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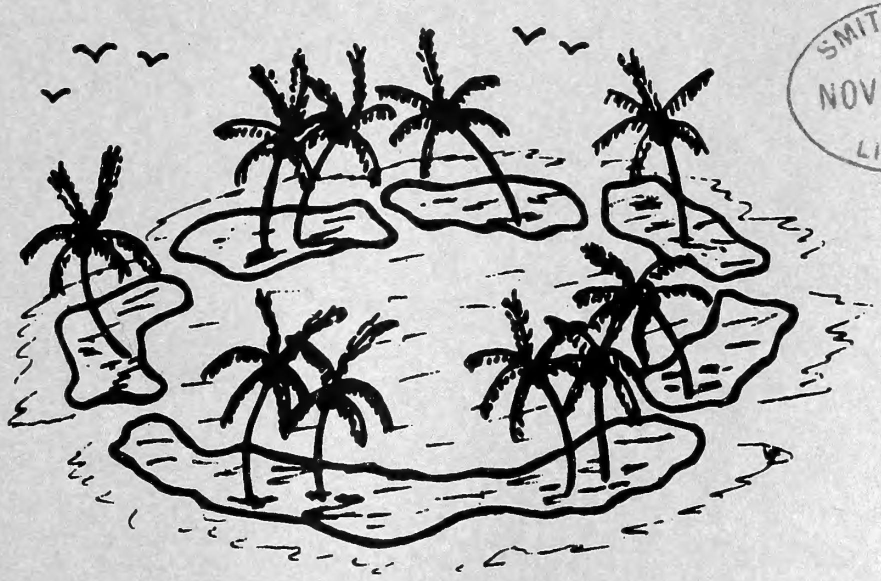
Nos. 128 through 135

August 15, 1969

ATOLL RESEARCH BULLETIN



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NOTES ON BIRDS OBSERVED IN THE COMOROS ON BEHALF OF THE SMITHSONIAN INSTITUTION

by A. D. Forbes-Watson

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NOTES ON BIRDS OBSERVED IN THE COMOROS ON BEHALF OF THE SMITHSONIAN INSTITUTION

by A. D. Forbes-Watson [1]

Introduction

At the request of Dr. S. Dillon Ripley I visited the Comoros to ascertain conditions and regulations regarding the making of scientific collections there for the Smithsonian Institution. I spent a fortnight on the islands, and, whilst passing through Tananarive, Madagascar, made similar enquiries there. The results of this reconnaissance follow.

Whilst conducting this enquiry I was greatly helped by many people; I would like to take this opportunity to thank the following, who particularly went out of their way to help:

Air France was wonderful in providing introductions and in general facilitating my work. In particular, M. Louis Henry of Nairobi, Regional Manager for Africa, and M. S. Barthelez in Tananarive were most helpful.

On Grand Comoro, M. Pierre Besnault, of the Veterinary Department, was extremely kind and helpful, and also assisted with translations. He also took me to various places of interest.

I would like to thank Dr. S. Dillon Ripley for permission to publish this report, and my friend Con Benson for helpful advice and suggestions.

The avifauna cannot be expected to have altered much in the last seven years, but two species, both introductions, have increased their range since 1958. One, indeed, is a recent introduction and is not mentioned by Benson. This is the domestic pigeon "*Columba livia*," which I saw at Fomboni (Moheli), Mutsamudu (Anjouan), and Dzaoudzi and Mamoutzou (Mayotte). The other, *Passer domesticus*, has spread on Pamanzi Islet, Mayotte and has reached the main island; I also saw it on Anjouan, whence it had previously not been recorded.

Suggestions for further work in the Comoros

I think that a further expedition to the Comoros so soon after the 1958 expedition would be justified on the following grounds:

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1. A further general study collection, which, if properly conducted, would have no detrimental effect on the population of any Comoran endemic, would be of great importance in the New World, where there is apparently no comprehensive collection from the Comoros. The only races which might have only a few birds left both occur on Anjouan; *Otus rutilus capnodes* may be extinct, and only one *Accipiter francesii pusillus* was seen in 1958.

2. Although the avifauna is now probably fairly well-known taxonomically, it is very likely that some new and exciting discoveries can be made, particularly on Moheli and Mayotte. The best means would be extensive mist-netting in the more remote forests. This method still produces surprises in such a well-worked area as Kenya.

3. An enormous amount has still to be learnt of the biology and ecology of all the species. One aspect which would repay study is the voices, particularly of closely-related birds, i.e., the two *Microscelis* spp. and the two *Nesillas* spp. on Moheli; *Dicrurus* spp. (why is there none on Moheli?); *Nectarinia* spp. and *Zosterops* spp. To this end sound-recordings would be the most valuable material, and might help in elucidating relationships.

4. The breeding of the endemic genus *Humblotia*, confined to Grand Comoro, is still unknown. Benson (p. 71) suggests October as being the most likely month in which to find the nest.

5. There are still some interesting problems on relationships to be worked out, i.e., *Nesillas mariae* and *N. typica* on Moheli; as Benson says he only arbitrarily separated a particular population as belonging to the new species. Only field observation, particularly regarding voice, can really show whether he "guessed" correctly (see his discussion p. 81). On Moheli there are two species of *Microscelis*, *M. crassirostris* and *M. madagascariensis*, and their comparative ecological requirements are still unknown. On Grand Comoro the latter species has two so-called phases, which may, possibly, actually represent populations of sibling species.

6. There are some interesting points regarding distribution:

a. Why is there no *Otus*, *Accipiter* or *Dicrurus* on Moheli?

b. Why is there no *Coracopsis*, *Nesillas* or *Turdus* on Mayotte?

c. Why are *Treron australis* and *Cyanolanius madagascarinus* confined to Moheli? It is not the closest island to Madagascar, from which their nearest relatives are known.

d. Why are only two species of swift known from each island; in all, except Grand Comoro, made up of *Apus barbatus* and *Cypsiurus parvus*? On Grand Comoro the former is replaced by *Chaetura grandidieri*, whose nearest relations are in Madagascar, and yet it only occurs on the farthest island from there.

Perhaps, with further collecting and observation, it may be found that the apparent gaps are only gaps in knowledge, and are not real gaps at all.

7. It would be interesting to know if any of the introductions have any effect on the indigenous avifauna. The recent introduction of domestic pigeons on Moheli, Anjouan and Mayotte may also, eventually, become of importance.

8. One or two of the off-lying islets would be worth investigating. I flew over Chaco Islet, off the eastern end of Moheli, and it was very "white-washed." On Anjouan a M. Flobert, who had been stationed on Moheli, said he had visited Chaco once, but could tell me nothing of the birds he saw there, except that there were many, were nesting, and that some dived at him. Few sea-birds have been recorded from the Comoros, but this may be a breeding-station of species not often seen near land, i.e., Procellariidae, Sulidae and Fregatidae.

Since the above was written I have received a letter from Benson (pers. comm. 18 Nov. 1965), in which he says: "I do *most sincerely* hope that you can go back to the Comoros. I have always hankered to go back myself to clear up various points. . . I can't tell you how pleased I should be if you can . . . . The real plum for you to make for is Moheli, which was almost unknown before we went there, and where due to the vagaries of boats we could only spend two weeks. You might well pick up something there which we didn't find at all. And do try and find out what you can about the ecology of the two *Microscelis* and two *Nesillas* there. You also ought to look at the small islands off the coast for sea-birds. Chaco (eastern side) we couldn't get to at all. Another plum would be to find a nest of *Humblotia* on Grand Comoro. We were there at the wrong time, and I'd guess October would be the time. Oh, I do hope you can manage this!"

The Comoro Islands

I spent a total of two weeks in the Comoros, in which time I visited all four islands. My itinerary follows:

12 Oct. 1965.	Nairobi-Tanarive, Madagascar
14	to Moroni, Grand Comoro
14-19	on GRAND COMORO
19	to Fomboni, Moheli
19-21	on MOHELI
21	to Mutsamudu, Anjouan
21-23	on ANJOUAN
23	to Dzaoudzi, Mayotte
23-28	on MAYOTTE
28	to Tananarive via Moroni
30	to Nairobi, Kenya.

All localities mentioned in the accounts, etc., can be found in the new 1:50000 maps of the archipelago. Briefly, the parts of each island I was able to get to were:

Grand Comoro: Moroni; west coast Moroni-Mitsamiouli-"Hole of the Prophet;" Mitsamiouli-La Grille; M'vouni, La Belvedere, Nioumbadjou on western slopes of Mt. Karthala; ridge between La Grille and Mt. Karthala.

Moheli: Fomboni and forest areas immediately above.

Anjouan: Mutsamudu, and coast to west of it; Mutsamudu-Bamboa-Domoni.

Mayotte: Dzaoudzi, etc., Pamanzi Islet; Mamoutzou and forest immediately above it; Lake Carrieni (= Dziani Carehani), via Combani and Passamainte; Mavingoni via Dembeni.

The last ornithological work done in the Comoros was that of the British Ornithologists' Union Centenary Expedition 1958, led by Mr. C. W. Benson. It spent a total of 100 days in the islands, from 6 August - 13 November 1958. I would like to express here my great appreciation of Benson's report (Ibis 103b, 1960:5-106) on this expedition. It was an invaluable guide to me whilst I was on the islands and, indeed, before I landed. The ornithological part of my report is based directly on his; the nomenclature used follows Benson or, if the species is not mentioned by him, Praed and Grant's name is used ("Birds of East and Northeast Africa," 2 vols.).

For an excellent general account of the islands, and detailed descriptions of each, I cannot do better than refer to Benson's paper. Since he was there in 1958 there have been only a few changes. The seat of government has moved from Dzaoudzi, Mayotte to Moroni, Grand Comoro. There are now extremely good large-scale maps of all the islands. Grand Comoro and Anjouan even have a few miles of bituminised roads. There is a Forest Officer actually stationed in the islands, at Moroni, and the government has recently purchased La Grille forest, but will still allow grazing therein.

List of Birds recorded from the Comoros

Endemics underlined; * new records (by Forbes-Watson 1965); GC Grand Comoro, A Anjouan, Mo Moheli, My Mayotte

1.	Podiceps ruficollis capensis		Mo	My*	A
2.	Phaethon lepturus lepturus	GC	Mo	My	A
3.	*Fregata ariel subsp.		Mo*		
4.	Ardea cinerea cinerea (= johannae)	GC	Mo	My	A
5.	A. humbloti		Mo	My*	A?
6.	Egretta alba melanorhynchos	GC	Mo	My	A
7.	*E. garzetta		Mo*		
8.	Ardeola ibis ibis	GC	Mo	My	A
9.	A. ralloides		Mo	?My	A?
10.	A. idae	?GC*		My	
11.	Butorides striatus rhizophorae	GC	Mo	My	A
12.	Dendrocygna viduata		Mo	?My	
13.	Milvus migrans parasitus	GC	Mo	My	A
14.	Accipiter francesii griveaudi	GC			
	pusillus				A
	brutus			My	

15.	Circus spilonotus macrosceles	GC	Mo	My	A
16.	Falco peregrinus radama/perconfuscus	GC	Mo	My	A
17.	F. newtoni aldabranus				A
18.	Coturnix coturnix africana	GC	Mo	My	A
19.	Numida meleagris mitrata	GC		My	A
20.	Porphyrio alleni	GC		?My	
21.	Gallinula chloropus pyrrhorhoa			My	A
22.	Charadrius hiaticula tundrae	GC	Mo	My	A
23.	Ch. leschenaulti	GC	Mo	My	
24.	*Ch. fulvus			My*	
25.	Ch. squatarola	GC	Mo	My	
26.	Arenaria interpres interpres	GC	Mo	My	A
27.	Calidris ferruginea	GC	Mo	My*	A
28.	C. minuta	GC			
29.	Crocethia alba	GC	Mo*	My*	
30.	*Philopachus pugnax	GC*			
31.	Tringa hypoleucos hypoleucos	GC	Mo	My	A
32.	T. nebularia	GC	Mo	My	A
33.	T. cinerea	GC*			A
34.	Numenius arquatus orientalis		Mo*	My	
35.	N. phaeopus phaeopus	GC	Mo	My	A
36.	Glareola ocularis	GC*		My	
37.	Dromas ardeola	GC		My	A
38.	Sterna bergii thalassina	GC	Mo	My	
39.	S. bengalensis par.	GC		My	
40.	Columba arquatrix polleni	GC	Mo	My	A
41.	Streptopelia picturata comorensis	GC	Mo	My	A
42.	S. capicola tropica	GC	Mo	My	A
43.	Turtur tympanistrius	GC	Mo	My	A
44.	Treron australis griveaudi		Mo		
45.	Alectroenas sganzini sganzini	GC	Mo	My	A
46.	Coracopsis vasa makawa	GC			
	comorensis		Mo		A
47.	C. nigra sibilans	GC			A
48.	Agapornis cana cana	GC	Mo	My	A
49.	Eurystomus glaucurus glaucurus	GC		My	A
50.	Leptosomus discolor discolor		Mo	My	
	gracilis	GC			
	intermedius (= anjouanensis)				A
51.	Alcedo vintsioides johannae	GC	Mo	My	A
52.	Merops superciliosus superciliosus	GC	Mo	My	A
53.	Tyto alba affinis	GC	Mo	My	A
54.	Otus rutilus pauliani	GC			
	mayottensis			My	
	capnodes				A
55.	Apus barbatus mayottensis		Mo*	My	A
56.	Cypsiurus parvus griveaudi	GC	Mo	My	A
57.	Chaetura grandidiori mariae	GC			
58.	Microscelis crassirostris moheliensis		Mo		
59.	M. madagascariensis parvirostris (= rostrata)	GC	Mo	My	A
60.	Coracina cinerea moheliensis		Mo		
	cucullata (= sulphurea)	GC			
61.	Humblotia flavirostris	GC			

		GC	Mo	My	A
62.	Terpsiphone mutata comorensis	GC			
	voelzkowiana		Mo		
	pretiosa			My	
	vulpina				A
63.	Turdus bewsheri bewsheri				A
	comorensis	GC			
	moheliensis		Mo		
64.	Saxicola torquata voeltzkowi	GC			
65.	Nesillas mariae		Mo		
66.	N. typica moheliensis		Mo		
	brevicaudata	GC			
	longicaudata				A
67.	Cyanolanius madagascarinus comorensis		Mo		
68.	Dicrurus fuscipennis	GC			
69.	D. forficatus potior				A
70.	D. waldeni			My	
71.	Corvus albus	GC	Mo	My	A
72.	Acridotheres tristis tristis	GC	Mo	My	A
73.	Zosterops senegalensis kirki	GC			
74.	Z. mouroniensis	GC			
75.	Z. maderaspatana comorensis		Mo		
	anjouanensis				A
76.	Z. mayottensis mayottensis (= semiflava)			My	
77.	Nectarinia notata moebii	GC			
	voeltzkowi		Mo		
78.	N. humbloti humbloti	GC			
	mohelica		Mo		
79.	N. comorensis				A
80.	N. coquereli			My	
81.	Passer domesticus arboreus	GC	Mo	My	A*
82.	Foudia madagascariensis	GC	Mo	My	A
83.	F. eminentissima eminentissima		Mo		
	consobrina	GC			
	algondae			My	
	anjouanensis				A
84.	Lonchura cucullata scutata	GC	Mo	My	A

Summary of forms recorded on each Island

			GC	Mo	My	A	
	1..	Endemic Genus	1	-	-	-	a
	7..	" species with no races	3	1	2	1	b
	1..	" " " 2 "	1	1	-	-	c
	1..	" " " 3 "	1	1	-	1	d
Total	9..	" "	5	3	2	2	e
	5..	" races of endemic species (c+d)	2	2	-	1	f
	34..	" " confined to 1 island	12	9	5	8	g
Total	39..	" " " " 1 " ((f+g)	14	11	5	9	h
	2..	" " " " 2 islands	1	1	-	2	i
	1..	" " " " 3 "	1	1	1	1	j
	8..	" " " " 4 "	8	8	8	8	k
Total	50..	" " (h+i+j+k)	23	21	14	20	l
Total	57..	Forms (b+l)	26	22	16	21	m
	1..	Endemic race no longer recognized	1	1	1	1	n

	GC	Mo	My	A (cont'd)
Other species (not endemic)	35	34	38	30 o
Total species (1+(m+n+o)	62	57	55	52 p

Additions to the Comoro Avifauna

In October 1965 I made the following 15 extensions to range:

2 Species new to list (It is interesting to note that both these species have recently been observed in Madagascar - see O. Appert *L'Oiseau et la Revue Française d'Ornithologie* Vol. 35, 1965:66-69.)

		GC	Mo	My	A
24.	Charadrius fulvus			My	
30.	Philopachus pugnax	GC			
1 Species suspected but not previously identified					
3.	Fregata ariel		Mo		
1 Species reinstated					
7.	Egretta garzetta		Mo		
10 Extensions to previously known range					
1.	Podiceps ruficollis			My	
5.	Ardea humbloti			My	
27.	Calidris ferruginea			My	
29.	Crocethia alba		Mo	My	
33.	Tringa cinerea	GC			
34.	Numenius arquatus		Mo		
36.	Glareola ocularis	GC			
55.	Apus barbatus		Mo		
81.	Passer domesticus				A
1 Species not certainly identified					
?10.	Ardeola sp., probably idae	GC			
14+?1		3+?1	5	5	1

Breeding behaviour of some sort was seen in the following 18 species, including 4 (marked *) for the first time in the Comoros:

		GC	Mo	My	A
2.	Phaethon lepturus			My	
6.	Egretta alba		Mo		
8.	Ardeola ibis				A
11.	Butorides striatus	GC			
14.	Accipiter francesii			My	
*15.	Circus spilonotus				A
*50.	Leptosomus discolor			My	
*51.	Alcedo vintsioides				A
59.	Microscelis madagascariensis			My	
64.	Saxicola torquata	GC			
*68.	Dicrurus fuscipennis	GC			
70.	Dicrurus waldeni			My	
71.	Corvus albus	GC	Mo	My	A
72.	Acridotheres tristis			My	
77.	Nectarinia notata		Mo		
80.	Nectarinia coquereli			My	
81.	Passer domesticus	GC	Mo	My	
83.	Foudia eminentissima		Mo		
		5	5	9	4

Of these, nesting has never been observed before in two species:

50. Leptosomus discolor
68. Dicrurus fuscipennis

Notes on Individual Species

Immediately following each name is the known status of each species on each island:

GC Grand Comoro, Mo Moheli, My Mayotte, A Anjouan
- not recorded
? of possible occurrence
no brackets if seen by me
() if not seen by me
* extension of previously known range
_ breeding noted by me

1. Podiceps ruficollis — - (Mo) My* (A)

Noted once, when 12 were seen at one time on the crater lake Dziani Dzaha on Pamanzi Islet, Mayotte on 23 October. All were in pairs, except for one group of four birds.

This is an extension of range, but Benson (p. 30) thought it might occur on this very lake.

2. Phaeton lepturus — (GC) (Mo) My (A)

Only seen in one place, at Moya on the east coast of Pamanzi Islet, Mayotte, on 24 October, when at least 20 were seen along two miles of cliffs. Their central tail-feathers were exceptionally long in all cases, except that two birds had short central tail-feathers, but were otherwise in adult dress. They were flying in pairs along the cliff near the top, and were fluttering at particular spots where thick bush grew to the brink. Only one was seen to land, and it immediately took off again. They gave a creaky tern-like "kyi!" in flight. An apparent display was seen, in which the lower bird of a pair flying along the cliff carried on in normal flight, but the other, which was a few feet behind and above it, made fairly prolonged glides above its partner with half-raised wings and the tail depressed vertically.

I looked carefully at each bird seen, and all were of this species.

3. Fregata ariel — - Mo* - -

A pair was seen, and positively identified, on 20 October at Fomboni, Moheli. They were sailing without a wing-flap in the direction of Grand Comoro, visible on the horizon.

Benson (p. 104) saw Frigate Birds on Moheli and Anjouan, but could not identify the species.

4. Ardea cinerea — (GC) Mo My A

On 19 October I saw a single bird on the rocks to the east of Fomboni, Moheli.

On 23 October one was seen on the coast near Mutsamudu, Anjouan.

In the crater lake Dziani Dzaha on Pamanzi Islet, Mayotte two single birds were seen 23 October. On 24 October six were seen together on the beach at the eastern end of the islet at high tide; they allowed a fairly close approach.

5. Ardea humbloti - (Mo) My* (?A)

On 24 October on the east side of Pamanzi Islet, Mayotte a single bird was watched for a half an hour from a distance of about 40 yards. It was fishing in the thicker weedy patches in shallow water on the reef at low tide. It was seen to catch a deep-bodied green fish c. 6 inches long. The bird stood motionless with lowered head and wings slightly out from the body; it gave a quick jab and caught the fish just behind the gills. It was maneuvered quickly until its head pointed down the bird's gullet, and immediately swallowed. About five minutes later it caught another very small fish in the same way.

There was a black plume on the nape. The legs were dull grey-brown; bill dull yellowish, blackish at the base; iris yellow.

6. Egretta alba (GC) Mo My A

Not seen on Grand Comoro.

Near Fomboni, Moheli four nests were found in a baobab tree on 19 October. There were three well-grown young and 13 adults in the tree. They were seen along the coast nearby on several occasions, fishing in tidal rock-pools. The colors of the soft parts were the same in all birds seen: iris pale yellow; bill yellow; tarsi black.

Near Mutsamudu, Anjouan one was seen on 23 October.

On Mayotte one was seen on the airfield at Dzaoudzi on 14 October.

The Moheli colony is evidently the same as that seen by Benson (p. 32). From his photograph (pl. 3) the nests seem higher than when I saw them.

7. Egretta garzetta - Mo* - -

One was seen on the airfield at Fomboni, Moheli on 21 October. Old records are rejected by Benson (p. 103) as probably referring to E. alba. This bird was in the white phase, and was observed closely.

8. Ardeola ibis GC Mo My A

On Grand Comoro it was seen twice on 17 October, at Mitsamiouli three birds were seen in a Baobab tree; and two tame birds were accompanying cattle at Ivembeni at c. 2500 feet a.s.l.

On Moheli it was more common. There were at least 40 near Fomboni, and on 20 October 30 were seen to fly to the river at dusk. All were seen to take repeated drinks of the fresh water.

On Anjouan there was a colony of perhaps 40-50 nests in two trees near the shore, not far from the airfield to the north of Mutsamudu.

A few of these birds had bright pink bills, as is recorded by Benson (p. 33) for one of his Anjouan birds. I have seen the same thing in Africa and Madagascar at breeding colonies.

On Mayotte they were fairly common, and there must have been a roost somewhere near the airfield on Pamanzi Islet, as many birds could be seen flying steadily in that direction each evening. Most of these came from Mayotte itself, and small groups flew fairly low over the water from there, usually passing close to Dzaoudzi. I looked for a breeding colony near the airfield, but saw no sign of one.

9. Ardeola ralloides - (Mo) (?My) (?A)
Not seen by me, and only three were seen by Benson (p. 34) on Moheli.

10. Ardeola idae ?GC* - My -
At Mitsamiouli, Grand Comoro a small heron, probably of this species, was seen flying into a thick plantation on 17 October. If it was indeed this species it is new for the island - A. ralloides has also not been recorded, but it is less likely to occur (see Benson:34).

An undoubted A. idae in non-breeding dress was seen on 24 October at the eastern end of Pamanzi Islet, Mayotte in a thick bush just above the beach. When disturbed it settled in shallow water on the reef. Benson saw several on Lake Carrieni, but this was completely dry when I visited it on 25 October.

11. Butorides striatus GC Mo My (A)
On 17 October a few birds were seen at Mitsamiouli, Grand Comoro and at the "Hole of the Prophet" on the northwest coast; and a single bird was seen in a plantation at Maouni at c. 2000 feet a.s.l.

On 18 October a nest containing two eggs was found in the small mangrove swamp at Voidjou, about five miles north of Moroni, Grand Comoro. This nest was about 15 feet up on a thin outer branch of a mangrove tree; it was a small stick structure about 15 inches across and six inches deep. The eggs were in a slight depression about two inches deep and nine inches across. The nest was built of thin twigs, and there was no lining. The eggs are clear pale blue, measuring 40.5 x 28, 39 x 29 mm.

On Moheli only one was seen, and that in a coconut plantation on 20 October.

None was seen on Anjouan.

On Mayotte there was generally one to be seen on the reefs near Dzaoudzi, Pamanzi Islet. This bird, a female, was seen closely enough to note that the iris and legs were bright yellow. All the males seen had orange legs; thus, in four males which were seen on the reefs off the eastern shore of the islet, all had orange legs.

12. Dendrocygna viduata - (Mo) (?My) -
Not seen by me, and Benson only saw one party on Moheli (p. 35).

13. _Milvus migrans_ GC Mo My A

Common on all four islands, especially at Fomboni, Moheli and at Dzaoudzi, Pamanzi Islet, Mayotte. One on Moheli was seen eating a very large crab claw. One had been killed on the airfield at Dzaoudzi, presumably by an aircraft. No sign of breeding was seen.

14. _Accipiter francesii_ GC - _My_ (A)

One was seen at Nioumbadjou, Grand Comoro on 18 October. It was molesting a pair of _Dicrurus fuscipennis_ which had a nest, and I suspect the Goshawk robbed it. This bird was dark grey above, paler on the head, and pure white below (but see Benson:36). The iris was dark yellow.

On Mayotte they were not uncommon, and a pair was watched near the _Leptosomus_ nest on a few occasions on 25 and 26 October. The female was seen calling on several occasions "ooi! i! i!" and "oo, oo i! i!. . . i! i!," etc., the "oo" descending slightly; also "ooik!." The female bent her head when the male made a querying "werk!. . . werk! . . .," and he mounted her with a loud series of "i-ik!. . . i-ik!. . . ." He stood on her back for a short time before actually mating, and the act was accompanied with beating wings. He made another, but unsuccessful, attempt shortly afterwards. The female solicited by turning her back to him and bending down; after this attempt he stood upright on her back for a short time. The male was very noticeably the smaller sex.

Two nests were found on Mayotte on 26 October above Passamainte. They were large stick structures in the tops of Eucalyptus trees, and were about 200 yards apart.

All those birds seen were extremely tame.

15. _Circus spilonotus_ GC Mo My _A_

Seen on all four islands.

On Grand Comoro a bird was seen twice, flying along the forest edge at Nioumbadjou on 18 October.

On Moheli several were seen on 19 and 20 October, also flying along the forest edge.

On 21 October a nest was found on Anjouan at c. 2000 feet a.s.l. near the bitumen road from Mutsamudu to Bambao, where it crosses the ridge at Col de Patsi. It was on the top of a road-cutting, and consisted of a flat pad of dried grass tufts (each being complete) on the tops of some short Lantana bushes about two feet from the ground. It contained three eggs (one of which was broken when I was descending the slippery cutting), which were unmarked bluish-white, slightly nest-stained, measuring 47 x 37, 48.5 x 38 mm. The birds were seen to change over: the female dropped slowly to the nest with motionless wings, after a short time the male left and circled overhead. The female flushed from the nest when I was close to it.

On Pamanzi Islet, Mayotte a beautiful black-shouldered grey male was seen on 23 October on the rim overlooking the crater lake Dziani Dzaha.

16. Falco peregrinus (GC) (Mo) (My) (A)
Not seen by me.

17. Falco newtoni - - - (A)
There is apparently only one old record. Not seen by me or Benson.

18. Coturnix coturnix (GC) Mo My (A)
A few were seen and heard in cultivation near Fomboni, Moheli on 20 October.

Two were seen in long grass on Pamanzi Islet, Mayotte on 23 October.

The call is exactly the same as that heard in Africa.

19. Numida meleagris (GC) - (My) (A)
Not seen by me, but I was told by M. Besnault that he had seen one a week before (i.e., on 7 October or thereabouts) on Grand Comoro.

20. Porphyrio alleni (GC) - (?My) -
Not seen by me or Benson.

21. Gallinula chloropus - - (My) (A)
I visited Lake Carrieni, Mayotte on 25 October, but it was dry and there were no birds there. Those seen on this lake by Benson (p. 42) had probably retreated to the perennial stream mentioned by him.

22-35. Shorebirds
For details of sightings turn to the table on the following page.

22. Charadrius hiaticula GC Mo My (A)

23. Charadrius leschenaulti GC Mo My -

24. Charadrius fulvus - - My* -
A single plover seen with seven Charadrius squatarola was identified as belonging to this species, and this identification has been confirmed by Mr. John G. Williams. It was slightly smaller than its companions, but had the same build; it was more brownish, darker on the crown and had a pale eye-stripe; there was no definite wing-pattern and it did not have black axillaries; the center of the belly was very slightly darker.

25. Charadrius squatarola GC Mo My -

26. Arenaria interpres GC Mo My (A)

27. Calidris ferruginea GC Mo My* (A)

28. Calidris minuta GC - - -

29. <u>Crocethia alba</u> GC Mo* My* -

30. <u>Philopachus pugnax</u> GC* - - -

31. <u>Tringa hypoleucos</u> GC Mo My (A)

32. <u>Tringa nebularia</u> (GC) Mo My (A)

33. <u>Tringa cinerea</u> GC* - - (A)

34. <u>Numenius arquatus</u> - Mo* My -

35. <u>Numenius phacopus</u> GC Mo My (A)

<u>Shorebirds</u>

All those species of Charadriidae and Scolopacidae previously recorded were seen by me; in addition, one plover (24) and the Buff (30) had not been previously recorded. The following table summarizes all sightings. All are coastal except for those at the crater lake Dziani Dzaha. No species was seen on Anjouan.

	22	23	24	25	26	27	28	29	30	31	32	33	34	35
<u>Grand Comoro</u>														
Oct. 16 Moroni	.	.	.	.	.	.	.	.	.	3	.	.	.	1
17 Mitsamiouli	1	30	.	1	12	4	1	2	.	3	.	3	.	3
Hole of the Prophet	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Mitsamiouli	1	.	.	.	8	.	.	.	1	6	.	.	.	.
18 Voidjou	.	.	.	.	.	.	.	.	.	3	.	.	.	.
19 Moroni airstrip	2	.	.	.	.	.	.	.	.	.	.	.	.	3
<u>Moheli</u>														
Oct. 19 Fomboni	4	5	.	3	4	30	.	4	.	2	1	.	1	8
"	.	.	.	2	4	31	.	.	.	1	.	.	.	1
" airstrip	.	.	.	.	.	.	.	.	.	.	.	.	.	2
20 "	3	6	.	6	4	.	.	5	.	3	.	.	.	7
<u>Mayotte</u>														
Oct. 14 Dzaoudzi airstrip	.	.	.	.	.	.	.	.	.	.	.	.	.	3
23 Dzaoudzi	4	3	.	1	3	.	.	2	.	1	.	.	1	4
"	11	5	.	4	7	.	.	.	.	.	.	.	.	5
Dziani Dzaha	4	.	.	4	.	52	.	.	.	13	22	.	1	2
24 Dzaoudzi	3	.	.	.	3	.	.	.	.	.	.	.	.	4
Moya	.	.	.	.	.	.	.	.	.	1	.	.	.	3
Dzaoudzi airstrip	70	.	.	.	.	.	.	.	.	.	.	.	.	.
shore near airstrip	5	45	1	12	35	1	.	31	.	11	12	.	.	2
S. " " "	.	.	.	20	.	.	.	.	.	.	.	.	.	4

There seem to have been more Palaearctic migrants in 1965 than in 1958 (see Benson 42-44).

36. <u>Glareola ocularis</u> GC* - My -
On 19 October three were seen on the Moroni airstrip, Grand Comoro. When the birds were on the ground the head was bobbed rapidly up and down, especially if someone approached closely. A plover-like "wit!" was heard.

On 24 October one was seen on the Dzaoudzi airstrip, Mayotte. It was eating a large insect on the ground; two <u>Acridotheres tristis</u> flew to it from about 30 yards away and chased the Pratincole, but it flew off with the insect and the Mynas got nothing.

One of the Moroni birds was a beautiful male.

37. <u>Dromas ardeola</u> GC - (My) (A)
Only seen once, on 17 October at Mitsamiouli, Grand Comoro when three (one adult, two apparently immature) were seen together on some rocks near the sea. The adult made a "druuet" in flight, and a creaky "witik! witik!" with bill wide open when approached closely; this is probably an alarm-note.

38. <u>Sterna bergii</u> GC (Mo) My -
One was seen on 14 October at Moroni airstrip, Grand Comoro.

On 23 October 73 were counted resting on a sand-bank near Dzaoudzi, Pamanzi Islet, Mayotte. They were seen there daily thereafter. Several single birds were seen on various occasions not far away, and were probably members of the same flock.

39. <u>Sterna bengalensis</u> (GC) - (My) -
Not seen by me or Benson.

40. <u>Columba arquatrix</u> GC Mo My (A)
Not seen on Anjouan.

On Grand Comoro it was seen on Mt. Karthala (Nioumbadjou, La Belvedere) and La Grille. On Moheli it was seen as low as c. 300 feet a.s.l., and it was seen on Mayotte on several occasions. All these sightings were in forest. They are much tamer than their relatives in Africa.

41. <u>Streptopelia picturata</u> GC Mo My A
Seen on all four islands, and common in cultivation as well as in forest, but always near clearings or tracks or just inside the forest-edge. Also seen in a mangrove swamp at Voidju, Grand Comoro.

The call is deeper than that of <u>S. capicola</u>, and was written thus: a deep, slow "cuc- <u>coo</u> oo!" with the second syllable accented; a similar, but shortened, form "ooo-wu," the second syllable being much deeper, was also heard; also, a deep "oo-wah!her," with the last note sounding like a hoarse inhalation.

A bird bought by M. Besnault from some youngsters on Grand Comoro had the soft parts as described by Benson (p. 47), except that the pale chestnut iris was paler near the pupil.

42. Streptopelia capicola GC Mo My A

Not uncommon in cultivation, and seen on all four islands. They were sometimes seen together with S. picturata, but in general were more prone to be confined to open cultivation, plantations and the dry coastal shrub. The call was exactly the same as that heard in Africa.

43. Turtur tympanistrius GC Mo My (A)

Not seen on Anjouan. On the other islands it was seen or heard in thickets and overgrown cultivation from sea-level to c. 1500 feet a.s.l. The call is exactly the same as that heard in Africa.

44. Treron australis - (Mo) - -

Not seen by me, but I was unable to get to Bandamale, Moheli, which was the only place where Benson obtained it.

45. Alectroenas sganzini GC Mo My (A)

Not seen on Anjouan, but on the other islands it was not uncommon in forest. It has the habit of sitting in the open in a conspicuous place, and is very tame.

Calls were a deliberate deep "wu" or "wow(u)," and "ou," the "u" being deeper.

46. Coracopsis vasa GC (Mo) - (A)

Only seen on Grand Comoro, at La Belvedere, Nioumbadjou and La Grille in forest, and also once flying over a coconut plantation at c. 300 feet a.s.l. In flight it looks quite unlike any African parrot, and reminded me strongly of an elongated ragged crow with a truncated head. They were very tame and allowed a close approach; thus, on 18 October I stood watching a pair eating fruit in a tree about ten feet from me. Normal parrot-like screeches were the usual noises made; a pair mating at La Belvedere on 15 October were making a "woo-oo," the second note descending.

47. Coracopsis nigra GC - - (A)

Only seen on Grand Comoro, and there only on Mt. Karthala, at La Belvedere and Nioumbadjou. In habits it is very like C. vasa, but it is more inclined to feed in the mid-stratum. This species is also tame; in flight it had the same crow-like appearance as the larger species.

48. Agapornis cana GC (Mo) My (A)

Seen in cultivation and plantations on Grand Comoro and Mayotte; they were more common on the latter and flocks of 20 were not unusual.

49. Eurystomus glaucurus (GC) - My (A)

Only one was seen, on 25 October near Mamoutzou, Mayotte; it was sitting motionless in the top of a tree overlooking the forest.

50. Leptosomus discolor GC Mo My (A)

Not seen on Anjouan. On the other islands it was commonest on Mayotte. A nest was found on this island on 25 October - for a full description see A. D. Forbes-Watson Ibis vol. 109, 1967:425-430, "Observations at a nest of the Cuckoo-Roller Leptosomus discolor."

51. Alcedo vintsioides GC Mo My A

Seen on all four islands.

On Grand Comoro three were seen on the coast (one at Itsandra, and two at the "Hole of the Prophet") and one in a coconut plantation at Memboidjou at c. 1000 feet a.s.l.

On Moheli one was seen on a perennial stream above Fomboni at c. 500 feet a.s.l.

On Mayotte one was seen in the mangrove swamp near Mamoutzou on 25 October.

On Anjouan an occupied nest was found on 20 October in an earthen road-cutting on the coastal road east of Mutsamudu. It was about 1-1/2 inches in diameter, a small tunnel about five feet above the road. Both parents were seen, and both puffed up the white patches on the sides of the neck. The bill was black, feet bright orange. Another bird was seen on two occasions on the dam on the road from Mutsamudu to Bambao at c. 700 feet a.s.l.

52. Merops superciliosus (GC) Mo My (A)

Only seen on Moheli and Mayotte.

On Moheli several were seen in plantations and hawking over the beach, even, on occasion, catching flying insects actually over the sea. A pair was seen on 19 October near a river bank near Fomboni; though one of the birds had a bedraggled tail, no nesting-tunnel could be found. They were making soft quiet warbled "doodlededu" sounds.

On Mayotte many were noticed on Pamanzi and near Mamoutzou.

53. Tyto alba GC (Mo) My (A)

On Grand Comoro one was seen near Itsandra on 18 October at dusk in a coconut plantation.

On Pamanzi Islet, Mayotte two were disturbed in trees near the crater lake Dziani Dzaha on 23 October. On 24 October one was seen on the airstrip two hours before sunset. It flew to a stump in grassland, and sat for a few minutes looking down; after a while it flew to another stump, and did the same. It was not seen to attempt to catch anything, but no doubt it was hunting, as is recorded by Benson (p. 60).

On Mayotte I was told they were called "vurundulu" locally.

54. Otus rutilus (GC) - (My) (A)

Not seen by me, no doubt because I was unable to be in the correct habitat after dark.

On Mayotte I was told they were called "kitunturuki" locally.

55. Apus barbatus - Mo* My (A)

Seen on Moheli and Mayotte; it has not been recorded previously from the former.

On 19 and 20 October about a dozen were seen about two miles west of Fomboni, Moheli. A pair of these was seen at close range in strong sunlight - they were black (or very dark brown), with the wings browner than the back, and the throat was pale, but not conspicuously so; the tail was slightly forked.

On Mayotte a pair was seen near Dzaoudzi, Pamanzi Islet on 23 October, and many single birds and pairs were seen hawking above the forest on the main island.

Benson points out that some of these birds could, perhaps, be Apus apus, though this is less likely.

56. Cypsiurus parvus GC Mo My A

Common and conspicuous on all four islands near palm trees. No signs of breeding were seen.

57. Chaetura grandidieri GC - - -

Only known from Grand Comoro, where I saw it commonly in the forest near Nioumbadjou, and once near Itsandra at sea level.

Benson's comparison with Psalidoprocne spp. is apt, as it flies low along a track through the forest, patrolling back and forth, exactly as do Rough-wing Swallows in Africa.

58. Microscelis crassirostris - Mo - -

Only known from Moheli from one specimen. I saw a bird which was larger and darker than the ubiquitous M. madagascariensis on 19 October in forest near Fomboni at about 400 feet a.s.l. The call was slightly different from other bulbul calls heard in the islands, and was written as a repeated "chochuiry."

59. Microscelis madagascariensis GC Mo My A

A common and conspicuous bird throughout the archipelago, in any habitat from thickets and mangrove swamps to plantations and true forest. A pair was seen with building material on Mayotte on 26 October, and was apparently building a nest high in a forest tree. The usual note was a Pycnonotus-like chatter. An apparent alarm-call was a mewing "nyeeeea" or "mieeee(wi)!". The birds were usually bold and tame. They were often seen making long, vertical flights to catch a flying insect.

60. Coracina cinerea GC (Mo) - -

Only seen at Nioumbadjou, Grand Comoro; on 18 October several pairs

were seen in mixed bird-parties in the forest. They were usually found in the mid-stratum, and occasionally in the undergrowth. All those seen were of the grey (not olive) form. A male foraging low down in a tree was heard to make a chick (fowl)-like "seeoo, seeoo."

61. Humblotia flavirostris (GC) - - -
Especially looked for at Nioumbadjou, but not seen.

Benson (p. 72) says it is rare.

62. Terpsiphone mutata GC Mo My (A)
Not seen on Anjouan.

On Grand Comoro they were seen in forest at Nioumbadjou and La Grille, and in mangroves at Voidju. All males had white in the wing and comparatively short tails.

On Moheli several were seen in the forest near Fomboni at c. 500 feet a.s.l., and one was seen in Fomboni itself. Most of the males were of the very pale chestnut phase, as mentioned by Benson (p. 73).

On Mayotte they were very common. Most males were in the white phase, but a few were maroon-chestnut, with only short tails in contrast to those of the white phase. One of these maroon-chestnut birds, with the central rectrices just projecting, was associated with a party of Zosterops mayottensis. A pair near the Leptosomus nest spent a lot of time chivvying a pair of Accipiter francesii that were breeding nearby.

All notes heard were similar to those of T. viridis in Africa.

63. Turdus bewsheri GC Mo - A
On Grand Comoro it was only seen at La Grille, on 17 October; the three birds seen there were all high up in trees; one was pulling at some lichen on a branch, but whether this was for a nest, or whether it was searching for food, could not be ascertained.

On Moheli several were seen in forest and on forest-edges; they were mostly on the ground, but when disturbed would fly up into trees.

On Anjouan one was seen on 22 October in a ylang-ylang plantation.

64. Saxicola torquata GC - - -
Seen in grassy country above c. 2000 feet a.s.l. on Grand Comoro. Two immatures were seen along the track in forest on La Grille, and a female was seen with nesting material nearby, but not in forest.

In habits they were identical to African birds. Males were seen to make towering flights on several occasions, which were, perhaps, simply fly-catching flights, but might have been a form of display.

65. Nesillas mariae - (Mo) - -
Not seen, no doubt due to the fact that I was unable to visit the high forest on Moheli in the time available.

66. Nesillas typica GC (Mo) - (A)

Only seen on Grand Comoro at La Grille and Nioumbadjou in forest. They would skulk in the undergrowth, but would come out to take a look if one "squeaked," when they would make a sharp "chep."

67. Cyanolanius madagascarinus - Mo - -

Seen once, when four (a male and three females or young) were seen together on the forest edge above Fomboni, Moheli at c. 500 feet a.s.l. This group was industriously searching through the leaves of trees, and often came quite close to the ground. They were making a harsh "cgreh-cgreh," which might have been an alarm-note. The colors of their soft parts were as noted by Benson (p. 84).

68. Dicrurus fuscipennis GC - - -

A total of five was seen at Nioumbadjou, Grand Comoro on 18 October. Two of these were paired and had a nest. This was in forest near the track, and my attention was drawn to it by the antics of the drongos and an Accipiter francesii, which was apparently trying to rob the nest, and, indeed, I think it was successful. The hawk was close to the nest, and one of the drongos would land near it and spread the tail (which was noticeably brownish), making a chick(fowl)-like "chlew," and then attacking the hawk so viciously that it had to fly off. It came back after a short while, however, and I think it was then that it robbed the nest. It flew off again, after an attack by one of the drongos. The other then settled on the nest, but left again almost immediately - my impression was that the nest was then empty.

Unfortunately, the nest was inaccessible and I was unable to inspect it closely, but it was a neat substantial cup (for a drongo) about 30 feet from the ground, and was built in a small fork. In Africa D. adsimilis and D. ludwigii build nests which are slung in the fork, but in the present nest I was struck by the fact that it was built more on, rather than in, the fork (see also the account of D. waldeni).

69. Dicrurus forficatus - - - A

Two seen perched on sisal poles near Bambao, Anjouan, near sea level.

70. Dicrurus waldeni - - My -

Three birds were seen in forest on the east side of Mayotte above Passamainte on 26 October. Two of these were paired and had a nest in the thin twigs at the top of a Eucalyptus tree about 60 feet above the ground. This nest was conspicuous but was slung as in D. adsimilis and D. ludwigii in Africa (but see D. fuscipennis).

Benson never saw this species on the east side of Mayotte (p. 86).

71. Corvus albus GC Mo My A

Common throughout, and was even seen flying over forest, and it settled in degraded forest.

Breeding was obviously in full swing. On 15 October, at Itsandra, Grand Comoro a bird was seen flying with a stick. A total of 15 nests

was found; all were near the coast, except one near La Grille, which was at c. 2500 feet a.s.l. Details of all these nests are as follows: Grand Comoro, 17 October seven nests (two in figs, two in kapok, three in baobabs). Moheli, 19 October two nests (in baobabs, one in the same tree as the colony of Egretta alba).

20 October three nests (all in Baobabs).

Anjouan, 21 October one nest (in kapok near airfield).

Mayotte, 25 October one nest (in Dzaoudzi town square).

26 October one nest (near Mamoutzou).

On the beach at Fomboni, Moheli a freak was seen with two normal birds; this bird was completely featherless on some of the parts of the body where it would have had black feathers, i.e., the whole head, and most of the upper back and belly were bare; there were also some scattered white feathers on the rump and wings. I did not see any other crow molest it; indeed, its two companions seemed to treat it as a normal bird.

A crow was seen near a mangrove swamp near Mamoutzou, Mayotte with a fresh fish about four inches long, but this was probably not actually caught by the bird.

72. Acridotheres tristis GC Mo My A

Common and conspicuous throughout the archipelago, particularly in plantations and cultivation, but also in degraded forest on Mayotte, where a nest was seen on 26 October. This was built behind a large flake of bark high up in a tree.

A habit noted on all four islands, which I have not seen recorded elsewhere, is their association with domestic stock. Thus, it was seen perched on cattle on all four islands, and on donkeys on Moheli. On Moheli they were also seen near goats, but not actually on them. No doubt the "host" is mostly used as a beater, in the same way that Ardeola ibis and Merops nubicus do in Africa, and Onychognathus blythii on Socotra. But on two occasions Mynas were seen to peck at the bodies of the cows on which they were perched; I could find no sore, and perhaps an insect had alighted on the beasts. That Benson does not mention this widespread habit (in the Comoros) suggests that it may be a new habit. It would seem extraordinary, however, if this had developed simultaneously in such widely-separated localities remote from one another. Benson tells me that he did not observe this habit, but does not rule out the possibility that it did occur without him consciously noting the fact.

73. Zosterops senegalensis GC - - -

Very common throughout Grand Comoro except in the grasslands. It was usually in small bands, and sometimes, especially in forest, was associated with other species in bird-parties, but though travelling with them, the association would be a loose one and the Zosterops were often detached from the rest.

74. Zosterops mouroniensis (GC) - - -

Not seen by me, as time did not allow me to reach the heathzone on Mt. Karthala, Grand Comoro, the only locality from which it is known.

75. Zosterops maderaspatana - Mo - A

Seen by me on both Moheli and Anjouan, where it was particularly common in thickets near the coast.

76. Zosterops mayottensis - - My -

Fairly common on the east side of Mayotte and on Pamanzi Islet. On Mayotte a party was seen bathing in a small pool of water about 20 feet up in a tree in forest.

77. Nectarinia notata GC Mo - -

Fairly common on both Grand Comoro and Moheli, especially in the mid-stratum and canopy of forests, but was also found in plantations and thickets. Unlike Benson (p. 92) I found it not uncommon near sea level. The flight-call was a sharp "chip chip," which reminded me strongly of N. senegalensis in Africa. A male at Fomboni, Moheli on 19 October was preening near a destroyed nest, and was making a clear "chiew."

Two other nests were found in the mid-stratum of the forest above Fomboni, at about 400 feet a.s.l.: that of 19 October was built near the trunk of a tree about 20 feet above the ground. Unlike other sunbird nests I have seen, it was built in such a fashion that the entrance was at a tangent to the trunk and did not face outwards. The nest was very large for a sunbird, being about eight inches deep and six inches across. The porch was very well-developed, so much so, in fact, that the entrance-hole (about two inches in diameter) faced downwards, and the nest, apart from its materials, reminded me strongly of that of Ploceus sp. It was neatly and strongly made of fine grass and was lined very thickly with vegetable down. There was a fairly long strand of material at the top of the nest from which it was suspended. On 20 October another nest was found in exactly the same sort of place, and also faced tangentially to the tree. Its construction was identical to the other nest, except that it had been built onto an old nest (which also appeared identical, except that the entrance-hole faced in the opposite direction to that of the new nest). This incredible structure is over two feet in total length. Mr. John G. Williams tells me he has heard of nothing comparable in any other sunbird species. Both my nests were complete but empty; I might add that they were attached to the tips of thin drooping twigs.

78. Nectarinia humbloti GC Mo - -

In general, more common than N. notata, and found in the same habitats. It was seen feeding in coconut flowers on several occasions, which N. notata was never seen to do, but N. humbloti was never seen at banana flowers, at which N. notata was seen on several occasions. The present species was also seen in the mangrove swamp at Voidju, and an old nest was found there on 18 October. It hung from a horizontal twig, and was small and compact, with the entrance-hole roughly half-way

up the side (see also Benson:94). The bird was often seen in forest, and was generally found in the mid-stratum and more commonly in the low undergrowth, at times less than a foot above the ground, which is not mentioned by Benson.

The song is tinkly; on 19 October a male and female were both heard scolding "swear-swear."

79. Nectarinia comorensis - - - A

Common on Anjouan, and the song sounded very like that of N. humbloti.

80. Nectarinia coquereli - - My -

Not uncommon on Mayotte and Pamanzi Islet. It was particularly common in thickets and in plantations, etc. On 25 October near Mamoutzou a female was seen making repeated flights with nesting material. Her unfinished nest was easily found, hanging from the end of a bamboo-shoot, about three feet above the ground in a clump of bamboos. The nest was small and compact, but had a lop-sided appearance, due partly to a series of streamers fringing one side, and partly because the entrance-hole was more towards the opposite side. Unlike the nest of N. humbloti, in which the entrance-hole was half-way up, this of N. coquereli had the entrance-hole near the top (see also Benson:94-96, who also states that N. comorensis has a nest similar to N. humbloti in this respect). It was unlined.

Benson noted no calls. The male's song, heard on several occasions, was recorded by me as a warbling chitter "tiddle tiddle tiddle ti;" another note made by the male was a subdued warble "chewi-chui," and "swee-swee;" a male seen in the top of a palm was making a repeated series of soft "wiht!...wiht!...wiht!...wiht!...wiht!"; the flight-call was a subdued "swit." Near Dzaoudzi on 24 October five females were chasing each other in a tree with "brrrr"-ing wings; they postured at each other with vertical bills, when they would warble softly. When one was separated from the others it made a soft "wit."

81. Passer domesticus GC Mo My A*

Seen on all four islands; it had not previously been recorded on Anjouan, but I saw six birds in Mutsamudu on 21 October - had they been introduced or had they reached Anjouan unaided from one of the other islands? The former seems more likely for two reasons: Mutsamudu is the capital, and is where one would expect them to be introduced; and it is by no means the nearest point on Anjouan to any other island.

On Mayotte Benson only found it at L'Abattoir village, Pamanzi Islet (p. 98). I found it extremely common at the airfield, and thence all the way to Dzaoudzi. This spread has continued, and the House Sparrow had evidently just reached Mayotte itself, where I saw two pairs and a nest at Mamoutzou on 25 October.

On Grand Comoro, also, it has spread. Benson only found it in Moroni, but I saw it as far north as Tsoudjini. In Moroni itself, it was seen colonizing the new European houses to the north of the town,

even to the extent of building nests in unfinished houses with workmen still in attendance.

On Moheli it was seen in thickets, plantations and cultivation, as well as in Fomboni and other villages. Elsewhere, it was only associated with buildings.

Breeding was noted throughout the archipelago, with the exception of Anjouan. Some birds were building, but many evidently had young. The new modern government buildings in Moroni were especially appreciated by the sparrows; one of these buildings had circular holes about two inches in diameter in a blank wall - those occupied by sparrows were easily identified by the dirty marks under the holes made by the birds' feet and tails. The occupied ones were all near the top of the building about 30 feet above the ground.

Two abnormal birds were seen: a male in Moroni which had a deep chestnut breast and upper chest, and a rather smaller black bib than normal; and an almost completely albino bird at the airfield near Fomboni, Moheli.

82. *Foudia madagascariensis* GC Mo My A

Seen on all four islands in cultivation, plantations and forest-clearings. It was seen occasionally in degraded forest. They were usually in small flocks, but at least 50 were seen together on 17 October near Memboudju, Grand Comoro in the grass of an overgrown plantation. The only males seen in breeding-plumage were on Mayotte from 23 October onwards. A beautiful bird was seen on Moheli on 19 October, whose whole body was a rich deep orange-gold.

83. *Foudia eminentissima* GC Mo My A

Seen on all four islands, mostly in forest, but also in plantations occasionally.

On 19 October several nests, most of them old, were found along a perennial stream above Fomboni, Moheli at about 600 feet a.s.l. One had three eggs nearly ready to hatch; they were rather pointed, and were plain pale blue. The nest was about 12 feet above the stream, and was built into a straggly upright shrub, so that it was supported from below. It was made of grass and twigs, and was lined with fine grass-heads, which had been stripped of their seeds. It was neatly made and inconspicuous, and measured about eight inches in height and about eight inches across; the entrance was in a slight tube, about two inches in diameter, and faced downwards. The other nests found were similar, but some had a layer of moss built into the upper part, forming a sort of th.

84. *Lonchura cucullata* GC (Mo) My A

Unaccountably, this bird was not seen by me on Moheli, though Benson records it as being common there. On the other islands it was common, and was usually found in little parties in cultivation, plantations, thickets and along road-sides, but was also seen once just within the forest at Nioumbadjou, Grand Comoro. No signs of breeding were seen, except that on 15 October there were several immatures in a group seen at Itsandra, Grand Comoro.

ATOLL RESEARCH BULLETIN
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FOUR SOUTHWESTERN CARIBBEAN ATOLLS:
COURTOWN CAYS, ALBUQUERQUE CAYS, RONCADOR BANK AND SERRANA BANK

by John D. Milliman

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FOUR SOUTHWESTERN CARIBBEAN ATOLLS: COURTOWN CAYS, ALBUQUERQUE CAYS, RONCADOR BANK AND SERRANA BANK

by John D. Milliman [2]

ABSTRACT

The environment and ecologic zonations of four southwestern Caribbean atolls (Courtown Cays, Albuquerque Cays, Roncador Bank, Serrana Bank) are discussed. Although the atolls vary in size and configuration, the same general zonations are present at each.

Fewer than 10 species constitute more than 95 percent of the reef corals; the small number of species, however, is somewhat balanced by the different growth forms of several major species. Although coral and algae are abundant, other fauna and flora are sparse. The absence of starfish and scarcity of marine grasses is notable.

The ecologic zonations of the four atolls are similar to other Caribbean reefs, but have a luxuriance reminiscent of Indo-Pacific reefs. The emergent *Millepora* zone (comprised primarily of *Millepora alcicornis*, *Palythoa mammillosa* and red algae) on the outer edge of the windward reef flat appears to be the ecologic equivalent of the Indo-Pacific algal ridge. The lack of massive red algal encrustations on the reef flats is the main character differentiating these Caribbean atolls from those of the Indo-Pacific.

Most oxygen uptake by the reef waters occurs on the outer reef, probably the outer 50 to 100 m; trapping of oxygen by crashing waves accounts for a significant amount of this. Primary plankton productivity apparently contributes very little oxygen to the reef flat waters.

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INTRODUCTION

Darwin (1851) believed that there are no true atolls in the Atlantic. However, by defining an atoll as a geomorphic form (rather than by origin, as Darwin did), Bryan (1953) listed 27 Atlantic atolls, 26 of which are in the Caribbean. A more reasonable estimate might be 15. Prior to 1966, five Caribbean atolls had been extensively studied: Alacran Reef (Kornicker and Boyd, 1962; Hoskin, 1963), The British Honduras atolls, Lighthouse Reef, Glover's Reef and Turneffe Islands (Stoddart, 1962), and Hogsty Reef (Milliman, 1967a, 1967b).

In May and June, 1966, the Caribbean Reef and Atoll Program (CRAP) cruise conducted aboard the R/V GERDA, Institute of Marine Science, University of Miami, visited four other Caribbean atolls. These atolls, Courtown Cays, Albuquerque Cays, Roncador Bank, and Serrana Bank, are located in the Southwestern Caribbean, east of the Miskito Bank (Figures 1 and 2). In many respects these atolls bear close climatologic, oceanographic, and geologic resemblance to many Pacific atolls: 1) the climate is tropical and being 200 km windward of the Central American mainland, has little seasonal change (see below); 2) the windward fetch is more than 2,000 km; 3) the atolls are surrounded by deep water (deeper than 1,000 m) and may be the only atolls in the Caribbean with volcanic basement (Milliman and Supko, 1968).

This paper presents a discussion of the morphology, ecology and oceanography observed on the atolls during the cruise.

Acknowledgements

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Regional setting

Courtown Cays (12°24'N, 81°25'W) (Figure 3) and Albuquerque Cays (12°10'N, 81°50'W) (Figure 4) are two small atolls, lying about 200 km east of Nicaragua, seaward of the continental shelf. Both atolls belong to the Republic of Colombia, and are within the jurisdiction of San Andres (12°29'N, 81°43'W), an uplifted limestone island. The longitude of Courtown Cays is listed as 81°28'W (U.S. Hydrographic Office, 1952). Radar bearings from the R. V. GERDA, however, showed Courtown Cays as being 33 km (or 18' longitude) east of San Andres. Assuming that the coordinates of San Andres, having a commercial airport, are accurate, the longitude of Courtown Cays is 81°25'W.

Roncador Bank (13°34'N, 80°04'W) (Figure 5) is about 200 km northwest of Courtown Cays and 140 km west of the volcanic island, Providencia. Serrana Bank (14°16'N, 80°20'W) (Figure 6), the largest

of the four atolls, lies about 70 km north of Roncador. Both atolls are under joint ownership by Colombia and the United States.

All four atolls appear to have volcanic foundations. However, in some cases the depth to volcanic basement may be considerable (Milliman and Supko, 1968). Whether this volcanism was related to Tertiary volcanic activity on the Nicaraguan mainland (McBirney and Williams, 1965) is not known.

Climate and Oceanography

Climatic values from the oceanic quadrant 10-15°N, 80-85°W (U.S. Hydrographic Office, 1952) are used since there are no recorded observations for any of the four atolls. The mean annual air temperature is 26.7°C, with a 1° range in monthly values. Winds are primarily from the E-NE, with mean monthly velocities varying from 3.2 to 6.2 m/sec. The atolls are relatively "wet," the measured rainfall on nearby San Andres averaging about 175 cm/yr (Parsons, 1956). Assuming that the rainy season coincides with that on the mainland, most rain falls from June through December.

The sea surface temperature averages 27.3°C, with a 2° range of mean monthly values. Ocean currents and waves like the wind are predominantly out of the E-NE. Tides on the atolls are mixed with a strong diurnal component. Tidal ranges are small, averaging .3 to .6 m. Changes in wind and barometric pressure often cause variations in water level greater than those caused by normal tides. A mean increase in water level of 6 cm occurs during the period of August through November, and a mean decrease of 9 cm occurs during March (U.S. Naval Oceanographic Office, 1965, personal communication).

History

The exact dates of discovery of these atolls are not known. Parsons (1966) wrote that Serrana Bank was "discovered" by (and subsequently named for) Pedro Serrana, a Spanish sailor who was ship-wrecked on its shores sometime prior to 1520. Judging from Spanish shipping activity in the area, the locations of Albuquerque, Courtown and Roncador probably were known long before the end of the 16th century.

None of the sand cays on the atolls had sufficient land to warrant colonization. But the neighboring islands of San Andres and Providencia, with rich soils and stragetic location, were the object of many colonial exploits. The islands were first settled by English puritans in 1631; their colony lasted only 10 years before it was overthrown by the Spanish. From 1641 to 1822 the islands fluctuated between Spanish and English rulers, with an occasional conquest by Jamaican pirates. Although the islands have been under Colombian rule for the past 150 years, most islanders (mainly descendents of African slaves) speak English and are Protestants. The complex history and sociology of San Andres and Providencia Islands are discussed by Parsons (1956) and Newton (1914).

Courtown and Albuquerque Cays have been visited by San Andrean and Providencian natives for many years. Fishermen remain at these atolls for several months, collecting both fish and turtles. Shacks and lean-tos are located on Sand, East and Middle Cays at Courtown, and on North Cay at Albuquerque. While Cayman islanders have hunted turtles on both Roncador and Serrana Banks, the main interest in these two atolls was the guano deposits on their cays. In the mid 19th century, with the increased need for fertilizer, the United States claimed possession of Serrana and Roncador Banks, on the pretense that James W. Jennett had "discovered" these cays during the civil war (Parsons, 1956). Although Colombia also laid claim to the atolls, pointing out that they had been discovered 300 years before (see above), the dispute continued until most all the guano had been removed by American companies. In 1928, the United States and Colombia agreed to joint ownership to the atolls, provided that Washington maintain lights at both atolls. Parsons (1956) discusses this history further.

Previous Studies

Although San Andres and Providencia had been visited by the U.S. Steamer ALBATROSS (U.S. Comm. Fish and Fisheries, 1886), the Pinchot South Sea Expedition (Pinchot, 1930), the Fifth George Vanderbilt Expedition (Vanderbilt, 1944), and the Catherwood-Chaplin West Indies Expedition (von Ripper, 1949), only the Vanderbilt expedition stopped at the neighboring atolls. The visits at each atoll were brief, a total of three days at Serrana and Roncador, and one day at Courtown and Albuquerque. Published observations include reports on the birds (Bond and DeSchauensee, 1944), the fish (Fowler, 1944) and crustaceans (Coventry, 1944) collected at these atolls.

Numerous other cruises have passed these atolls, taking various oceanographic observations. But to the best of the writer's knowledge, no other cruise had studied these atolls.

Methods

In order to gain insight into the ecology, oceanography, and geology of these atolls, the following data were collected: 1) sediment samples; 2) environmental distribution within the atolls; 3) bathymetry within the atoll; 4) meteorologic and hydrographic measurements within the atoll; 5) bathymetric and magnetic profiles and rock dredges on the outer slopes.

The dates spent at each atoll were: Courtown Cays, May 12-19, Albuquerque Cays, May 20-24, Roncador Bank, June 4-7, Serrana Bank, June 8-13. Additional data were collected at San Andres, May 28-29 and at Providencia, May 31-June 1. The data collected should be viewed in light of the limited time available at each atoll. This is especially true for the ecologic observations, which should be treated as preliminary.

While sediment samples were being collected (mainly by skin diving) the nature and depth of the bottom, together with prominent species of

coral, algae and other organisms, were noted. The clarity of the water also allowed us to observe general changes in the bottom morphology and communities from an outboard skiff.

Several hydrographic stations within the lagoon of each atoll were occupied by the R. V. GERDA (Figure 7). Various hydrographic and meteorological measurements were taken hourly. Most stations were occupied for one day, although some for much longer or shorter durations.

Current velocities at the surface, mid-depth and 1/2 m above the bottom were measured by a Savonius rotor, registered on a digital meter. In shallow depths only surface and bottom readings were taken. Current directions were estimated from both the ship's head and the wire angle. A thermistor, attached to the current meter, was used to measure water temperature. Unfortunately the thermistor broke during the first hydrographic station at Courtown Cays. Thereafter a standard "bucket" thermometer, with an estimated accuracy of 0.5°C, was used.

Concurrent with these oceanographic observations, air temperature (in the shade) and wind velocity and direction were measured. The wind velocities observed during this cruise were generally greater than normal (see above), suggesting that the currents may have been somewhat faster than normal. The wind (and current) direction (except for Roncador) and air and water temperatures, however, did seem normal.

At Courtown Cays salinity samples of the surface and bottom waters were taken twice daily, at noon and midnight. At Albuquerque Cays and Serrana Bank one set of salinity samples was taken at each station. No samples were taken at Roncador Bank.

ATOLL ECOLOGY

General

Each atoll has the same basic environments: the reef front, windward reef flat, lagoon (together with patch reefs), and leeward reef flat (figure 8). To save space, these environments are discussed, followed by a discussion of the unique characteristics of each atoll.

Reef Front

The windward reef front drops steeply to a depth of about 5 m, gradually slopes to about 18 to 20 m, and then again steepens. The width of this reef front varies, but is generally less than 500 m (Figure 8). Because of the high surf conditions at Roncador and Serrana, only the reef fronts at Albuquerque and Courtown Cays were studied; even there surf limited the time spent on the reef front.

Montastrea annularis is the most prominent coral in depths exceeding 5 m. In shallow depths *Acropora palmata*, oriented into the surf, grows profusely. The prominence of this coral is characteristic

of the shallow reef fronts of most Caribbean reefs (Shinn, 1963, and other references cited below). Other corals include *Agaricia agaricites* and *Acropora cervicornis*, the latter usually found in depths greater than 2 m. The hydrocoral, *Millepora alcicornis*, is prominent in shallow depths. Red algae, primarily *Goniolithon*, encrust reef rock and loose coral rubble.

Reef pinnacles, composed mainly of *M. annularis* and *A. palmata*, are common just windward of the surf zone at the northeast corners of both Courtown and Albuquerque cays. These pinnacles, rising from depths of about 5 m often break the surface.

Aerial photographs indicate the presence of buttresses and grooves oriented normal to the reef flat. Although these features were neither well-developed nor continuous on those parts of the reef front investigated, their prominence on the outer reef flat (see below) infers that the buttress-groove zone is present on much of the reef front, although probably not as well-developed as at Jamaica (Goreau, 1959).

Windward Reef Flat

Outer Margin: Reefs on the windward reef flat are best developed on the north and northeastern sides of each atoll, where waves and currents are greatest. The southeastern reefs tend to be less well-developed.

The northeastern and eastern reef margins of all atolls are penetrated by a series of surge channels, 1, to 2 m deep, oriented normal to the reef front. Crashing surf forces swift currents through these channels onto the reef flat. The sides of the channels are lined with massive *Diploria*, *Montastrea annularis* and *Porites astroides*, the latter, in places, assuming a flat, sheet-like form. *Porites porites* and the green alga, *Halimeda opuntia* form large masses. Branching red algae, *Amphiroa* and *Goniolithon* are common and the pink conch, *Strombus gigas*, is locally abundant.

Growing on the buttresses (and on most of the outer reef pavement not penetrated by surge channels) is the prolific assemblage of *Millepora alcicornis*, the soft coral *Palythoa mammillosa*, and encrusting red algae (*Porolithon* and *Goniolithon*); *Agaricia agaricites* and *Halimeda opuntia* are often present in this community (Plate 1). This feature, here termed the *Millepora* zone, grows up to 40 cm above the low tide level, and occupies a near continuous zone, 15 to 20 meters wide, along the outermost margins of the windward reef flat (Plate 2). It is most thoroughly developed on the northeastern sides of the atolls where high surf continually splashes and washes the emergent colonies. Concentrations of *M. alcicornis* and zoanthid corals on reef crests have been noted at other Caribbean reefs (Goreau, 1959; Lewis, 1960; Kornicker and Boyd, 1962), but at none are they reported emergent at low tide.

The *Millepora* zone seems to be the ecologic equivalent of the leeward portions of the algal ridge and *Acropora cuneata* zone found on Pacific atolls (Wells, 1954). In each area plate-like corals are

encrusted with red algae and zoanthid corals, and are exposed to low tide (see Tracey, Ladd and Hoffmeister, 1948, Plate I, Figure 2; Emery, Tracey and Ladd, 1954, Plate 19, Figure 2). The zone, however, cannot really be called an algal ridge because massive red algae do not actually form the basic structure. Rather algae and the soft corals encrust emergent colonies of Millepora.

Just leeward of the Millepora zone is an environment of prolific coral growth, 20 to 50 m wide, termed the "Diploria zone," because of the abundance of that genus, especially D. clivosa; Lewis (1960) has described a similar zone at Barbados. Depths range from a few cm to over 1 m. The massive growth form of Montastrea annularis is prominent with lesser amounts of A. palmata (also in massive growth form), Millepora alcicornis, Porites astroides and P. porites. Thickets of Acropora cervicornis are present on the more leeward portions of the Diploria zone. Corals of every major hermatypic species, plus many species of algae, grow up to 1/2 m above low tide level (Plate 3). Although these organisms are exposed above mean low tide level for relatively long durations, they are able to survive by means of intermittent surf splash.

Halimeda opuntia, growing in large mounds, is a prominent sediment contributor. The sea urchin, Diadema antillarum, is also common, especially in holes and crevices. At some transects the windward reef flat is almost devoid of coral, the reef pavement and any available rubble being covered with encrusting algae. Red algae form large hemispherical masses, up to 25 cm in diameter. Many have hollow interiors, where they probably once encrusted dead coral.

Inner Reef Flat: The inner reef flat is defined by a sudden increase in depth leeward of the outer reef flat. Depths commonly increase from less than a few tens of cm to more than 1 m (Plate 4). The inner reef flat is largely devoid of coral although there are some Porites astroides, Montastrea annularis and Siderastrea, mainly in encrusting growth form. Covering large portions of the bottom are green algae (Halimeda, Penicillus, Rhipocephalus, Udotea, Padina), brown algae (Dictyota and Turbinaria) and red algae (Porolithon, Goniolithon, Amphiroa). Red algae are the most common type on the inner reef, encrusting much of the rubble that has been washed in from the windward reefs. The gastropods Strombus gigas and Astrea phoebia are locally common.

Lagoonward Margin: The leeward margin of the reef is generally 1 to 2 m deep, with occasional small reefs, primarily Montastrea annularis, Acropora cervicornis and A. palmata breaking the surface. Alcyonarians, very sparse on the outer reef, are somewhat more prominent in this zone. Green and brown algae are common. The marine grasses, Thalassia, Halodule, and Syringodium, are completely lacking, except in sheltered spots leeward of some cays. This contrasts with the abundance of reef flat grasses on Alacran Reef and the British Honduras atolls (Kornicker and Boyd, 1962; Stoddart, 1962). Green algae, especially Halimeda, and brown algae (Dictyota and Turbinaria) are the dominant plants on the lagoonward margin. Near the sand cays, Halimeda is especially prolific, as is evidenced by the widespread Halimeda sands on the cay beaches.

A common leeward feature of the lagoonward margin is a "sand cliff," which drops abruptly from the reef flat into the lagoon (Figure 10). Vertical relief is as great as 10 m, with slopes up to 35°. Similar steep slopes have been reported at Alacran Reef (Kornicker and Boyd, 1962) and Glover's Reef (Stoddart, 1962) in the Caribbean, and at Ifaluk Atoll (Tracey, et al., 1961) and Midway and Kure atolls (Gross, et al., 1968) in the Pacific. This steep slope may be formed by transport of reef flat sediment into the lagoon, suggesting a fore-set slope, or it may be a karst remnant of earlier Pleistocene low sea levels (MacNeil, 1954).

Lagoon

A large portion of the lagoon bottom at each atoll is covered with patch reefs. About 1/3 of the lagoon reefs are emergent, or come within a few meters of the surface. The rest are low-lying, rising no more than a few meters above the bottom (Plate 5). The massive and columnar growth forms of Montastrea annularis are prominent in shallow depths. The columnar (Lewis, 1960, p. 1143), pinnacle (Plate 6) and foliose forms are more characteristic of deeper patch reefs. Thickets of A. cervicornis are common on both shallow and deep reefs. There are also varying amounts of Diploria, A. palmata, P. porites, Siderastrea, and Agaricia. Alcyonarians, which are sporadic on the shallow reefs, are abundant on many of the deeper patch reefs.

Most of the lagoonal organisms live on, in, or near these reefs. Green algae (Penicillus, Rhipocephalus, Halimeda) are locally common near reefs, but otherwise generally lacking. Polychaete tubes, emerging from the bottom, grow thickly in the vicinity of patch reefs. In deeper parts of the lagoon, sponges are common and reach large size. Judging from the number of mounds, burrowing organisms may play an important role in the ecology of the lagoon bottom. The portion of the lagoon floor not covered with reef is generally bare, except for occasional conchs (Strombus gigas), algal patches, and fecal mounds.

Leeward Reef Flat

At all atolls the leeward peripheral reefs are ill-defined and discontinuous. They appear to have been formed by the coalition of patch reefs. The reef organisms are similar to those on the windward reefs, but less abundant; also, the marked zonations seen on the windward reefs are generally absent. In places the reefs are dead, with Dictyota and other brown algae encrusting the reef flat bottom.

Courtown Cays

Courtown Cays (12°24'N, 81°25'W) is a lenticular atoll, 8-1/2 km N-S and 3-1/2 km E-W. The windward reef flat is indented in two places, giving the atoll an unusual bowed shape (Figure 3). Aerial photographs show that surge channel lineations are most conspicuous in the indented portions of the outer reef. The area of most prominent lineations is labelled "Buttress-Groove Zone" in Figure 3. The surge channels in this area have relief of 1/2 to 1 m, and extend into the reef front as a buttress-groove system. Depths shoal to about 1 m on the outer reef;

no sign of the emergent Millepora zone or other reef organisms was seen. The generally deep, reef-less bottom in this indented area is difficult to explain; perhaps it is related to the swift currents that seem to continually flow through this area.

The leeward reef at Courtown Cays is interrupted by a 2 km gap, resulting in a lagoon open to the NW. Sounding profiles showed no lagoon sill. Lagoon depths average about 12 m, although depths locally reach 16 m.

A large patch of sea grass, both Thalassia and Syringodium, extends some 100 m leeward of East Cay. The echinoid Tripneustes esculentus is particularly common in this grass patch.

Patch reefs cover only about 10 percent of the lagoon bottom. The reefs that break, or nearly break, the surface are usually located within the 10 m isobath (Figure 3). Coalescing patch reefs have nearly isolated the southern third of the lagoon.

Courtown Cays has five small cays and one rocky spit. Sand Cay is about 200 m by 25 m with a maximum height of about 1-1/2 to 2 m. The windward beaches are covered with encrusted reef rubble. A sand spit extends about 20 m south of the cay. Two prominent plant species grow on the cay: Tournefortia shrubs, with heights up to 1 m, and a low creeping vine (Euphorbia ?). A few coconut palms are also present. One unoccupied thatched hut, about the size and shape of a pup-tent, was found on the central part of the cay.

East Cay is the largest cay at Courtown Cays, being about 300 m by 100 m. Four bands of beachrock, paralleling the eastern shoreline, extend windward on the reef flat. The rock bands, about 20 m apart, probably represent previous shorelines, and suggest the lagoon migration of the cay (Plates 7, 8). The distinguishing feature on East Cay is the tall stand of coconut palms (Plate 7). Large Scaevola bushes grow on the lagoon side. Several other plant types were noted but not identified. A shack, on the lagoonward side of the cay, was occupied by a San Andrean fisherman and his dog.

A small rocky spit, composed of massive coral debris, lies at the southern tip of the peripheral reef. Wave refraction around the southern end of the atoll results in crashing surf from both the southeast and southwest. Nestled in between the large coral rubble were the nets of several frigate birds. No living land plants were seen on the spit.

Three small cays, Middle Cay, West Cay, and a sand spit, sit on patch reefs that collectively form the leeward peripheral reef. Only Middle Cay was visited. Most of the cay is surrounded by emergent patch reefs. The central vegetated portion of the cay is bordered by Tournefortia and Scaevola bushes. Low-lying, unidentified creepers cover most of the cay's interior. Several Providencian natives were living on the cay.

Viewed from an outboard skiff, West Cay apparently had vegetation similar to that on Middle Cay. The sand spit appeared to lack any plant life.

Four hydrographic stations were occupied in the Courtown Cays lagoon (Table 1). Air temperatures averaged about 28°C. Water temperatures were somewhat lower averaging 27.5°C, with small daily ranges. While the thermistor was operative little difference was noted in the surface and near bottom water temperatures at Station C-1. Salinities were between 36.1 and 36.4 o/oo. Definite salinity variations were noticed at Station C-1, where the salinity on the second day was more than 0.2 o/oo higher than the first day (Table 1).

Northeast winds seldom dropped below 7 m/sec. Current direction coincided with the wind. At C-1 current velocities averaged 5 cm/sec. Current velocities at the other three stations averaged 16 to 21 c/sec at the surface and 10 to 14 cm/sec near the bottom.

Albuquerque Cays

Albuquerque Cays (12°10'N, 81°50'W) is a nearly circular atoll, about 6-1/2 km E-W and 5 km N-S (Figure 4). Leeward peripheral reefs grow on a shallow, wide sand flat, which forms the lagoon sill. The sand flat deepens from about 3 to 5 m at the leeward reefs, to 10 to 15 m 3 km to the west. The flat is covered with small, low-lying patch reefs. Two navigable channels on the southwest and northwest broach the flat into the lagoon.

Lagoon depths are as much as 18 m but generally about 10 to 15 m. Patch reefs cover an estimated 20 percent of the lagoon bottom. These reefs are especially prominent in the northern half. Anastomosing patch reefs, corresponding to those described by Kornicker and Boyd (1962) as "cellular reefs," were seen in the northeastern parts of the lagoon.

The only sea grasses found on this atoll are strands of *Halodule* and *Syringodium*, on the northern and southern sides of North Cay.

Two islands, North Cay and South Cay, rise above the windward reef flat. North Cay measures 350 m N-S and 125 m E-W, and stands about 2 m high. South Cay, about 250 m to the south, is a smaller version (180 by 70 m) of North Cay.

Beachrock is present on the eastern shorelines of both cays (Plate 9). Several other bands extend windward, in a similar manner to those at East Cay on Courtown. Another beachrock outcrop, standing 1/2 to 1-1/2 m above sea level is located on the northern sides of North and South Cays. This elevated beachrock apparently continues across both cays; a soil pit dug in the interior of South Cay exposed a layer of beachrock, about 1/2 m thick and about 1-1/2 m above present sea level, overlying an unconsolidated *Halimeda* sand. Carbon-14 dates have not

		WIND				CURRENTS		WATER	
Station	Duration (hours)	Velocity* (m/sec)	Direction*	Air Temp. (°C)	Water Depth (m)	Velocity* (cm/sec)	Direction*	Temp.* (°C)	Salinity (o/oo)
1	35	9 (7-12)	55	27.4 (26.7-29.5)	10	5 (4-9)	235	27.6 (27.2-27.9)	(36.135-.347)
						5 (3-8)		27.6 (27.2-27.8)	
						5 (2-10)		27.5 (27.3-27.7)	(36.006-.390)
2	25	10 (8-12)	60	27.9 (27.0-29.5)	5	21 (6-30)	240	27.5 (27.3-27.7)	(36.236-.241)
						16 (5-29)			
						14 (4-28)			(36.193-.245)
3	25	10 (8-12)	53	27.9 (27.2-30.2)	12	16 (9-23)	233	27.4 (27.1-27.8)	(36.184-.187)
						15 (9-22)			
						12 (7-21)			(36.111-.179)
4	20	8 (7-11)	47	27.9 (27.1-28.9)	15	19 (13-23)	227	27.5 (27.2-27.8)	(36.291-.330)
						15 (11-19)			
						10 (4-17)			(36.205-.299)

Table 1. Hydrographic data collected at Courtown Cays, May 12-19, 1966. Asterisk (*) signifies that values presented are averages; numbers in parentheses represent the range in values.

		WIND				CURRENTS		WATER	
Station	Duration (hours)	Velocity* (m/sec)	Direction*	Air temp.* (°C)	Water Depth (m)	Velocity* (cm/sec)	Direction	Temp.* (°C)	Salinity (o/oo)
1	28	5 (3-8)	60	27.9 (27.0-30.4)	10	10 (4-17)	240	27.8 (27.2-28.3)	36.372
						7 (3-12)			
						5 (2-11)			36.791
2	6	7 (6-7)	75		5	10 (6-12)	255	27.7 (27.4-27.9)	36.350
						8 (5-11)			
						5 (0-9)			36.359
3	25	6 (2-8)	60	28.0 (26.9-29.5)	5	8 (4-19) [16]	240 [145]	27.7 (27.4-27.9)	36.382
						7 (3-12) [18]			
						6 (2-11) [4]			36.481

Table 2. Hydrographic data collected at Albuquerque Cays. Asterisk (*) signifies that values presented are averages; numbers in parentheses represent the range in values. For station 3, dominant average current values are given first; bracketed values represent average velocity and direction of tidal reversals.

been run on the rock or underlying sediments, so that the age and origin of this formation is open to speculation.

Coconut palms, Ficus trees and Scaevola shrubs are the prominent plants. The interior portions of both islands are so heavily wooded that little sun penetrates (Plate 10). On both cays the trees are lowest on the windward side and highest on the leeward side, giving the cays a swept-wing appearance. Because of the heavy, lush vegetation, the soils are more rich and loamy than at other atolls. When visited, four fishermen from Providencia were living on North Cay.

Bond and DeSchauensee (1944) reported nine species of birds on the two cays. Most were migratory birds, but some were boobies and terns. One species, a hummingbird (Anthracothorax prevostii hendersoni), is apparently a permanent inhabitant (Bond and DeSchauensee, 1944).

Three hydrographic stations, ranging in duration from six to 28 hours, were occupied at Albuquerque Cays (Table 2). Air and water temperatures were similar to those measurements taken at Courtown Cays. Salinity values were around 36.35 o/oo, somewhat higher than at Courtown Cays.

Winds were between 5 and 7 m/sec from the northeast. Surface currents at Stations A-1 and A-2 rarely exceeded 15 cm/sec, and averaging about 10 cm/sec; bottom currents were less, 5 cm/sec. Current direction, like wind, was in a westerly direction. The currents at Station A-3, at the southwestern lagoon entrance, reversed and flowed into the lagoon for a period of four hours. It is assumed that this current reversal was tidal.

Roncador Bank

Roncador Bank (13°34', 80°04'W) resembles the shape of a fish hook, being about 11 km long and 3-1/2 km wide (at its widest part) (Figure 5). The windward peripheral reef is better developed than at any of the other atolls. The Millepora zone, when visited during spring low tides, extended up to 50 cm above the water (Plate 2). The back reef, often awash at low tide, is considerably shallower than at the other atolls.

Large boulders, standing as much as 1-1/2 m above the reef flat, line extensive portions of the outer reef flat, especially near Roncador (Plate 11). The boulders are lenticular blocks, unlike either the negro heads found on Pacific reef flats or beachrock. Hopefully carbon-14 dates and petrographic study will shed light on the boulders' origin.

Leeward peripheral reefs at Roncador are the poorest developed of any of the four atolls. Except for a few large, but deep (2 to 3 m), patch reefs that define the peripheral reef to the south, the lagoon is open. Lagoon depths reach 18 m, but average between 10 and 12 m. Patch reefs dominate the lagoon's bottom. Almost the entire third of the lagoon is covered with low-lying reefs; interspersing sand patches probably account for no more than 30 percent of the bottom (Figure 9).

Roncador Cay is 400 m long and 150 m wide. Coral rubble covers most of the island. Walls of Montastrea and Diploria (Plate 12) perhaps were constructed by guano workers during the last century (see above). Vegetation is sparse; low-lying Tournefortia bushes and a creeping vine cover only small portions of the island.

This desolate rocky island is a far cry from the lush islands at Albuquerque Cays. Strangely enough, however, castaways have managed to survive on it. Newton (1914) writes that a ship carrying four men escaping from the Puritan rule on Providencia was wrecked on Roncador in 1636. In 1639 the sole survivor was rescued and returned to Providencia. As if living on this forsaken island for 2-1/2 years were not bad enough, after a Sunday evening service ". . . the rescued man was introduced (to the congregation) . . . to offer up public thanksgiving for his deliverance, to make confession for his vicious life, and to register a vow of future atonements." (Newton, 1914, p. 278). In the mid 19th century, an American ship was wrecked on Roncador, and the surviving crew remained on Roncador Cay for 10 days (Parsons, 1956).

Bond and DeSchauensee (1944) reported only three bird species, a hawk and two boobies, at the atoll. During our cruise Roncador Cay was covered with boobies and terns. These sea birds apparently migrate to Roncador and Serrana Banks during the spring months to nest (Parsons, 1956). Parsons (1956, p. 63) quotes the estimate that 25,000 sea bird eggs are annually removed from Roncador Bank by natives from San Andres and Providencia.

A sand spit, about 15 m in diameter, lies on the inner reef flat of the northeastern peripheral reef. The beaches are strewn with coral debris and Strombus shells. Another sand spit, also about 15 m in diameter, lies on the southern peripheral reef flat. No vegetation was seen on either spit.

During the stay at Roncador Bank, winds were from the south-southeast, probably in response to Hurricane Alma, which was in the northwestern Caribbean. Wind velocities averaged 7 m/sec (Table 3). Lagoon currents were generally less than 15 cm/sec, averaging between 8 and 11 cm/sec at the surface and 6 to 7 cm/sec near the bottom. Current direction coincided with wind direction. Air temperatures averaged 27.9°C. Water temperatures were somewhat higher, averaging between 28° and 28.4°.

Serrana Bank

Although Serrana Bank (14°16'N, 80°20'W) (Figure 6) is large (32 by 16 km), its morphology and ecology are generally similar to the other atolls. The peripheral reef is well developed on three sides; the western side is completely open.

Vanderbilt (1944) reported a "deep hole" on the reef flat by Southwest Cay. We found this hole to be about 9 m deep, and to have gradual sandy slopes, with some Syringodium blades on the bottom. This was the only grass seen at Serrana Bank. No thermocline was noted in the hole.

		WIND				CURRENTS		WATER	
Station	Duration (hours)	Velocity* (m/sec)	Direction*	Air Temp.* (°C)	Water Depth (m)	Velocity* (cm/sec)	Direction*	Temp.* (°C)	Salinity (o/oo)
1	25	7 (6-9)	145	27.9 (26.2-28.9)	11	11 (7-16) 10 (6-17) 6 (5-10)	325	28.4 (28.0-28.8)	
2	25	8 (6-10)	130	27.8 (27.4-28.6)	10	9 (3-15) 9 (4-12) 7 (3-13)	310	28.0 (27.8-28.4)	
3	22	7 (3-10)	165	27.9 (26.4-28.6)	12	8 (5-14) 7 (4-12) 6 (4-10)	245	28.0 (27.4-28.2)	

Table 3. Hydrographic data collected at Roncador Bank, June 4-7, 1966. Asterisk (*) signifies that values presented are averages; numbers in parentheses represent the range in values.

Two bands of patch reefs, one extending north from East Cay, the other extending south from the northern peripheral reef towards Little Cay, effectively divide Serrana lagoon in half (Figure 6). While lagoon water flows over these extensive reef complexes, water depths are too shallow for anything larger than a small skiff to pass over. The eastern string of patch reefs shoals rapidly from depths exceeding 15 m. Alcyonarians and gorgonians, together with *Monastrea* heads and scattered clumps of green algae, dominate the deeper bottom (Plate 13). As the reef shoals, *Acropora cervicornis* and *Monastrea annularis* increase in abundance. In depths shallower than 4 m, *Acropora palmata* oriented into the currents and *Millepora alcicornis* are prolific. The reef flat, up to 100 m wide, is generally 1 to 2 m deep. Most common corals on the reef flat are *M. annularis*, *Diploria*, *Acropora palmata*, *A. cervicornis* and alcyonarian corals. The encrusting coral, *Porites astroides*, is common throughout the patch reef.

A. cervicornis exhibits three distinctive growth forms on the patch reefs. On the reef front, in deeper water (5 to 10 m), the colonies are small and fragile; at shallower depths (1 to 3 m) on the reef front, the colonies are longer and thicker, but with few branches. On the reef flat, *A. cervicornis* is smaller, but with many thick branches.

The nature of the bottom and the zonation of the corals on these coalescing patch reefs are similar to the windward peripheral reefs. With an open lagoon fetch of some 3 to 5 km, considerable surf can crash onto these shallow reefs. In contrast to the windward peripheral reefs alcyonarians are more common, red algae less common, and the emergent *Millepora* zone and surge channel lineations are absent.

The second, leeward coalescing patch reef, while having similar zonations to the eastern patch reefs, lies on a broad sand bank, that extends some 2 km leeward of the reefs. Depths on the bank are seldom more than 3 or 4 m. It is difficult to conceive that this reef has produced that much sand; rather, the reefs probably have grown on the sand flat.

Lagoon depths east of the patch reef bands reach 20 m, but average about 15 m. An estimated thirty percent of the bottom in the eastern lagoon is covered with patch reef (Figure 10). Leeward of the linear reef bands is a broad shallow flat; depths seldom are greater than 10 m (Figure 6). In contrast to the eastern lagoon, only about 5 percent of this flat is covered with patch reefs (Figure 10).

Six cays are located on Serrana Bank. East Cay is a small islet covered with coral and mollusk (*Astrea* sp.) rubble. *Tournefortia* is the only plant present.

South Cay is about 150 m long and 25 m wide. Beachrock lines the seaward beach; the rest of the cay is composed of rubble and sand. The three species of plants present (*Tournefortia*, *Ipomoea* and *Euphorbia* were all sparse.

Little Cay lies on the southern edge of a linear reef band (see above) and forms the apex of an equilateral triangle with South and Narrow Cays. The cay is less than 100 m in diameter. Rubble lines the seaward (south and east) beaches, and beachrock is present on the south and west sides. The rest of the island is fine sand; no vegetation was seen.

Narrow Cay west of South Cay is essentially a rubble pile. The entire reef flat west of the cay is covered with beachrock and rubble. This may indicate the former position of the cay.

Southwest Cay is the largest island on any of the atolls visited. Its dimensions (about 500 m long, 200 m wide) contrast with five small cays on this atoll. Although most of the island is only a few m high, sand dunes on the south and west sides reach heights greater than 10 m.

For an island of this size there are surprisingly few plant species. A creeper vine covers much of the low-lying part of the cay. Several species of shrubs grow on the dunes. Two dilapidated huts are located in a small grove of coconut palms. These huts may belong to Cayman Brac natives who, according to Vanderbilt (1944), live on Serrana Bank most of the year, collecting guano and hunting turtles. No natives were seen during our visit.

Bond and DeSchauensee (1944) reported eight species of birds at Serrana. At the time of our visit large colonies of boobies and terns were nesting; we estimated about 100,000 birds on the cay. It is not hard to see why Parsons (1956) reports that 300,000 bird eggs are collected annually by Jamaicans, nor to understand why guano accumulated in such large quantities.

North Cay, located at the northern edge of the peripheral reef, is composed of sand and rubble. Three species of plants, Tournefortia, Ipomea and the small species of creeper seen at Southwest Cay were noted.

Five hydrographic stations, ranging in duration from 17 to 24 hours, were occupied at Serrana Bank (Table 4) at the first station, S-1, wind was from the southeast with an average velocity of 4 m/sec. The wind direction then shifted to the east and velocities increased to about 8 m/sec. These winds continued for the rest of the stay at Serrana.

Currents in the interior parts of the lagoon (stations S-1, S-4, and S-5) followed the wind direction. Currents near the lagoon entrances (S-2 and S-3), however, were seldom coincident with the wind. Water flowed out of the lagoon (S-3) or westward (S-2) during ebb tide. During flood and slack tide, water would flow into the lagoon. Thus the average current flowed into the lagoon. The fastest currents measured during the entire cruise were at these lagoon entrances; at S-3, currents often exceeded 50 cm/sec.

Air and water temperatures were in near equilibrium; the daily average for each being about 27.9°C. Salinities ranged between 35.93 and 36.04 o/oo.

		WIND				CURRENTS		WATER	
Station	Duration (hours)	Velocity* (m/sec)	Direction*	Air Temp.* (°C)	Water Depth (m)	Velocity* (cm/sec)	Direction*	Temp.* (°C)	Salinity (o/oo)
1	23	4 (1-8)	140	28.1 (27.7-29.3)	8	8 (4-18) 5 (4-7) 4 (2-9)	320	28.0 (27.6-28.6)	35.937
2	24	8 (6-11)	93	28.0 (26.4-28.6)	18	15 (12-22) [10] 16 (15-25) [8] 14 (9-22) [10]	010 [270]	28.0 (27.4-28.6)	36.048
3	24	9 (7-11	87	27.9 (27.5-28.6)	10	34 (19-53) [36] 35 (18-52) [37] 26 (14-43) [26]	000 [160]	28.0 (27.8-28.8)	36.004
4	19	8 (6-10)	93	27.9 (27.5-28.6)	5	34 (19-52) 23 (12-39)	270	27.9 (27.4-28.3)	35.993
5	17	11 (9-16)	90	27.4 (27.6-28.7)	5	18 (14-23) 16 (12-25)	270	27.9 (27.5-28.2)	35.953

Table 4. Hydrographic data collected at Serrana Bank, June 8-13, 1966. Asterisk (*) signifies that values presented are averages; numbers in parantheses represent the range in values. For stations 2 and 3 dominant average current values are given first; bracketed values represent average velocity and direction of tidal reversals.

DISCUSSION

Similar ecologic zonations are present at Courtown Cays, Albuquerque Cays, Roncador Bank and Serrana Bank. The outer windward reef flat is characterized by an emergent Millepora zone and a leeward Diploria zone. The deeper (1 to 2 m) inner reef flat lacks the prolific reef growth; red, green and brown algae are most conspicuous. Steep sand cliffs mark the sudden transition from the inner reef flat to the lagoon. Patch reefs dominate the lagoons. The leeward reefs seem to result from coalescence of patch reefs.

Some differences exist between atolls: 1) Serrana Bank, being larger than the other three atolls, has a more complex lagoon. Bands of coalescing patch reefs have almost divided the lagoon in two. 2) Courtown and Roncador, lacking leeward reefs, have more open lagoons. 3) Lagoon patch reefs are especially dominant at Roncador Bank, where an estimated 40 to 50 percent of the bottom is covered. 4) The sand cays at Albuquerque Cays have a relatively lush foliage and rich soil compared to the pioneer strandline plant communities at the other three atolls. 5) Elevated beachrock is found on the two islands at Albuquerque; large reef blocks line the outer periphery of the windward reef flat at Roncador.

Other than the abundant corals and calcareous algae, the fauna and flora of these Nicaraguan atolls seem depauperate. The most important mollusk and echinoderm species (Strombus, Astrea and Diadema) are only locally common. Several species of ophiuroids were collected or observed, but only the ubiquitous black Ophiocoma riisei was common. Virtually no holothurians were seen except Actinopyga agassizii, locally abundant on the reef flat and at moderate depths in the lagoon. Crustacea also were poorly represented. Many of the surface dwelling fauna such as Clypeaster rosaceus and Lytechinus variegatus, were not seen. Signs of an abundant molluscan infauna, such as empty bivalve shells, were also lacking. Prolific alcyonarian growth was primarily limited to deeper lagoon reefs.

Not one starfish was found. The total absence of this group and the almost complete lack of marine grasses was surprising, especially since both are common on the leeward shores of nearby San Andres and Providencia islands. This might suggest that the high current energy environments on the atolls have effectively limited the starfish and grass populations. It is interesting to note that the few grasses at the atolls were always found in the most restricted, low-energy environments.

Fowler (1944) was impressed by the numerous fish at Courtown Cays. He also mentioned catching several lobsters (Panulirus argus). The present writer was impressed by the small number and size of fish species and individuals. Extensive skin diving did not reveal many lobsters. The discrepancy between Fowler's observations and ours may be due to the fishing activity of the natives.

NICARAGUAN AND PACIFIC ATOLLS

Caribbean reefs and atolls are considered pale images of their Indo-Pacific counterparts, lacking in: 1) number of coral species (about 50 versus about 700 in the Indo-Pacific), 2) the emergence of corals at low tide, 3) an algal ridge zone, and 4) general reef maturity (Wells, 1957; Newell, 1959; Yonge, 1963). These conditions are true in the northern Caribbean, where the fetch is often short and the annual range of air temperature may be great. Yet at the Nicaraguan atolls, whose environment closely parallels many Pacific atolls, most hermatypic coral species can live exposed between tides. While no true algal ridge occurs on the Nicaraguan atolls, the *Millepora* zone, emergent at low tide, appears to be its ecologic equivalent.

The lack of coral species does not seem to inhibit the prolific reef growth. As in other Caribbean reefs (Goreau, 1959; Lewis, 1960; Stoddart, 1962), *Montastrea annularis* is the basic reef framework builder, estimated to comprise more than 60 percent (by volume) of the total coral. If the various species of *Acropora*, *Porites* and *Diplora*, and the hydrozoan *Millepora* were added to this estimate, the figure is closer to 95 percent. These few species adapt to the various environments of the atoll by assuming different growth forms. Thus, for instance, *Montastrea annularis* has four basic growth forms: the massive (and most common) form is typical of the reef flat and shallow lagoon; the columnar form is found throughout the lagoon; the pinnacle and foliose forms are more typical of the deeper lagoon reefs. Similarly, *Acropora palmata*, *Porites porites* and *Millepora alcicornis* were noted to have several growth forms.

The main difference between Nicaraguan and Pacific atolls is the relative importance of encrusting coralline algae. Although algal encrustations cover portions of the Nicaraguan reef flats, and coat much of the reef debris, massive colonies of red algae such as *Porolithon* species that form the Pacific algal ridges are lacking. Thus the Caribbean equivalent to the algal ridge is mainly *Millepora* coral; coralline algae only encrust the emergent colonies. The general lack of red algae in the Caribbean has also been noted by Goreau (1959) and Fosberg (1962).

Perhaps it is this lack of profuse encrusting red algae that limits the development of an algal ridge and results in the general lack of reef cohesiveness that so many Caribbean reef workers have observed (Wells, 1957; Newell, 1959). This point should be one of future study.

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APPENDIX: REEF PRODUCTIVITY MEASUREMENTS

by John D. Milliman and Conrad V. W. Mahnken [1]

Oxygen Uptake on Reef Flats

Hydrographic observations were taken on transects across the reef flats of Courtown and Albuquerque cays. Three stations comprised the transect at Courtown (between East and Sand cays); four stations comprised the Albuquerque transect (south of South Cay). Each station was marked by two anchored buoys, placed at approximately equally spaced intervals across the reef flat. The outermost station (referred to as Station 1) of both transects was about 75 m leeward of the outer reef margin; the innermost (Station 3 at Courtown, 4 at Albuquerque) was on the leeward margin of the inner reef (Figure A-1). Observations were taken at approximately three-hour intervals for 25 hours at Courtown Cays (23-24 May). The outer reef stations were not sampled at night due to hazardous navigation; values, however, could be inferred from sunset and pre-dawn values.

Water and air temperatures were measured with a "bucket" thermometer, the accuracy being about ± 0.5°C. Current direction and velocity were estimated by measuring the direction and time for a partially submerged small float to traverse a distance of 10 m. Salinity and oxygen samples were taken; the oxygen samples were then "pickled," using the standard Winkler technique, and stored in a dark, cool place until return to the laboratory.

Temperature, salinity and oxygen variations over the outer and inner reef flats of Courtown and Albuquerque cays are shown in Figures A-2 and A-3. The ranges of oxygen and temperature values generally were greater at the inner stations (higher values in daytime, lower at night). Salinity remained more or less constant, indicating the relatively rapid passage of water over the reef flat. Currents on the reef flat stations at Courtown Cays ranged from 26 to 36 cm/sec and at Albuquerque Cays, from 13 to 15 cm/sec.

Oxygen change in flowing waters is expressed as the product of mean current velocity, mean water depth, and the difference in oxygen concentrations between the up- and down-stream stations (Sargent and Austin, 1954). In calculating the oxygen uptake on the outer reef

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	NET OXYGEN GAINED (ml/cm/day)	NET OXYGEN LOST	NET OXYGEN GAIN (ml/cm/day)
Total reef flat (sta. 4 - ocean sta.)	69,000	8,200	60,900
Outer reef flat (sta. 1 - ocean sta.)	83,000	0	83,000
Inner reef flat (sta. 4 - sta. 1)	9,800	30,600	-20,800
ALBUQUERQUE CAYS			
Total reef flat (sta. 3 - ocean sta.)	75,000	7,300	67,700
Outer reef flat (sta. 1 - ocean sta.)	67,300	0	67,300
Inner reef flat (sta. 3 - sta. 1)	37,200	36,400	-800
COURTOWN CAYS			

Table A-1. Computation of oxygen gain and loss on the reef flats of Albuquerque and Courtown Cays.

		REEF STATIONS			
	OCEAN	1	2	3	4
Courtown	----	2.87	3.15	3.18	----
Albuquerque	----	2.37	2.23	4.47	5.38
Western Caribbean	2.21				

Table A-2. Twenty-four hour mean surface carbon fixation (g/Carbon/m^3/day) at stations across the windward reef of Courtown and Albuquerque Cays and oceanic waters of the western Caribbean.

flat, open-ocean and outer reef flat values represent up- and down-stream values, respectively [1/]; for the inner reef, outer reef and inner reef values represent up- and down-stream values. Oxygen uptake across the entire reef flat is reflected by the difference in open ocean (up stream) and inner reef (down stream) oxygen values. The calculated oxygen changes in the reef waters at Courtown and Albuquerque Cays are shown in Figures A-4 and A-5. Integration of the area above the zero lines quantifies the net gain in oxygen; similarly, the area below the line represents the net loss. These values (for 24 hours) are given in Table A-1.

At Courtown Cays most of the oxygen uptake occurred on the outer reef; the net oxygen gain on the inner reef flat was negligible. At Albuquerque Cays, waters flowing across the inner reef flat actually lost oxygen; the entire oxygen uptake occurred on the outer reef.

If the oxygen influx had been strictly due to biologic activity, a net loss of oxygen would have been expected at night. The fact that incoming ocean waters continually gained oxygen on the outer reef suggests that oxygen is entering from a non-biologic source. Blanchard and Woodcock (1957; cf. Gordon and Kelly, 1962) showed that the trapping of air bubbles by breaking waves can cause oxygen saturations up to 115 percent. With surf almost constantly crashing on the outer reefs of both atolls, oxygen can be continuously forced into the incoming waters.

Without a proper measure of the amount of oxygen physically put into the outer reef waters, no measure of reef productivity can be made. However, these observations lend support to the opinion that most oxygen uptake takes place on the outer edge of the reef (Gordon and Kelly, 1962).

Plankton Productivity

At each station the plankton productivity of the ambient reef waters was determined by measuring the C-14 uptake (Steeman-Nielsen, 1952). Dark and light bottles were inoculated with C-14 and incubated *in situ* in a series of short-term experiments corresponding in time to the periods between oxygen sampling. The bottles at each station were hung from lines attached between two buoys. Upon retrieval, the water in each bottle was filtered through an HA Millipore filter (0.45 μ pore opening). The individual filters were stored and later counted at

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[1/] In these calculations it is assumed that open ocean water approaching the atoll is in equilibrium with the atmosphere (that is saturated with oxygen). Indeed, oxygen values in the upper 20 m of nine oceanographic stations occupied by the U.S. Fish and Wildlife service GERONIMO during October 1965, in the vicinity of Courtown Cays, are essentially at saturation levels (101 - 1 percent; 4.45 ± 0.01 ml/l), with a diurnal range of hundredths of a ml/l (unpublished data).

the U.S. Bureau of Commercial Fisheries Radiobiological Laboratory, Beaufort, N.C.

Two trends of plankton productivity are apparent at both atolls: there is a marked diurnal variation in carbon fixation, and there is a net increase in carbon fixation from the windward to leeward stations across the reefs (Figures A-6, A-7; Table A-2). Because no synoptic oceanic measurements were taken for comparison, we have used a mean production estimate of five ocean stations occupied in October 1965, by the F. W. S. GERONIMO, along a section extending 700 km to the windward of Courtown and Albuquerque Cays. Since light inhibition is characteristic of shallow surface waters at all five ocean stations (maximum productivity is at 10 to 15 m) (unpublished data) the strong light must also tend to inhibit planktonic productivity on the shallow reef stations at the two atolls. Consistent with this assumption is the similarity between mean surface carbon fixation rates for the oceanic and windward reef stations (Table A-2). The successive increase in carbon fixation across the reefs in the direction of flow therefore may not be attributed to planktonic algae, but instead may be related to the presence of benthic algae, torn loose from the reef flat, which are not inhibited by high irradiance. The reef water possibly accumulates more benthonic fragments as it passes across the reef, accounting for the increase in net carbon fixation at the innermost stations. Thus the relative contribution of planktonic forms to the overall productivity of the reef flat is probably nil; Odum and Odum (1955) reached a similar conclusion.

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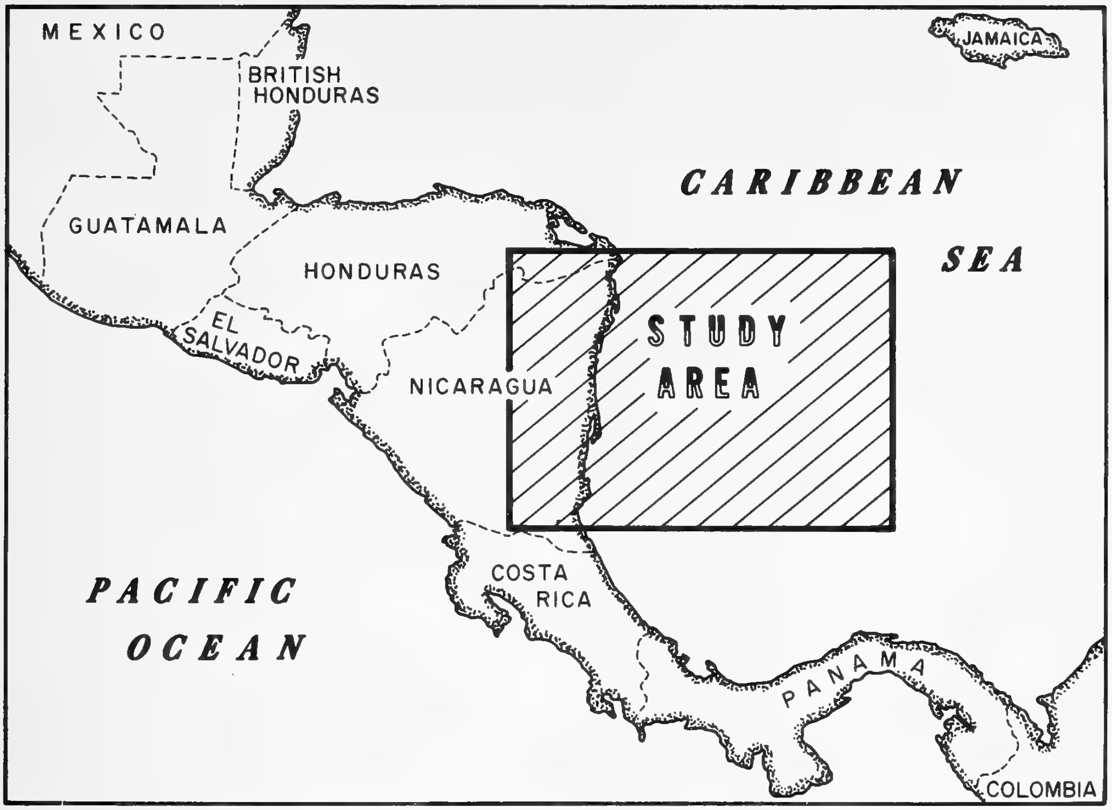
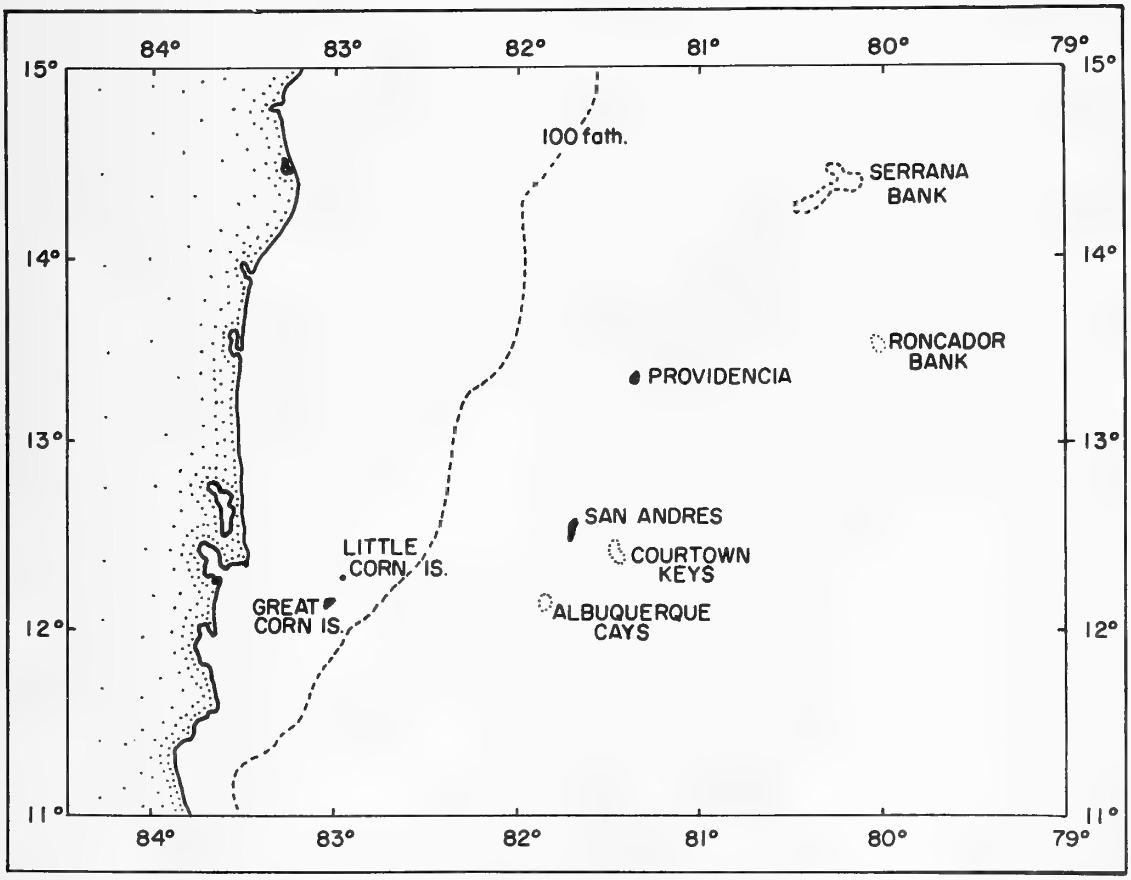
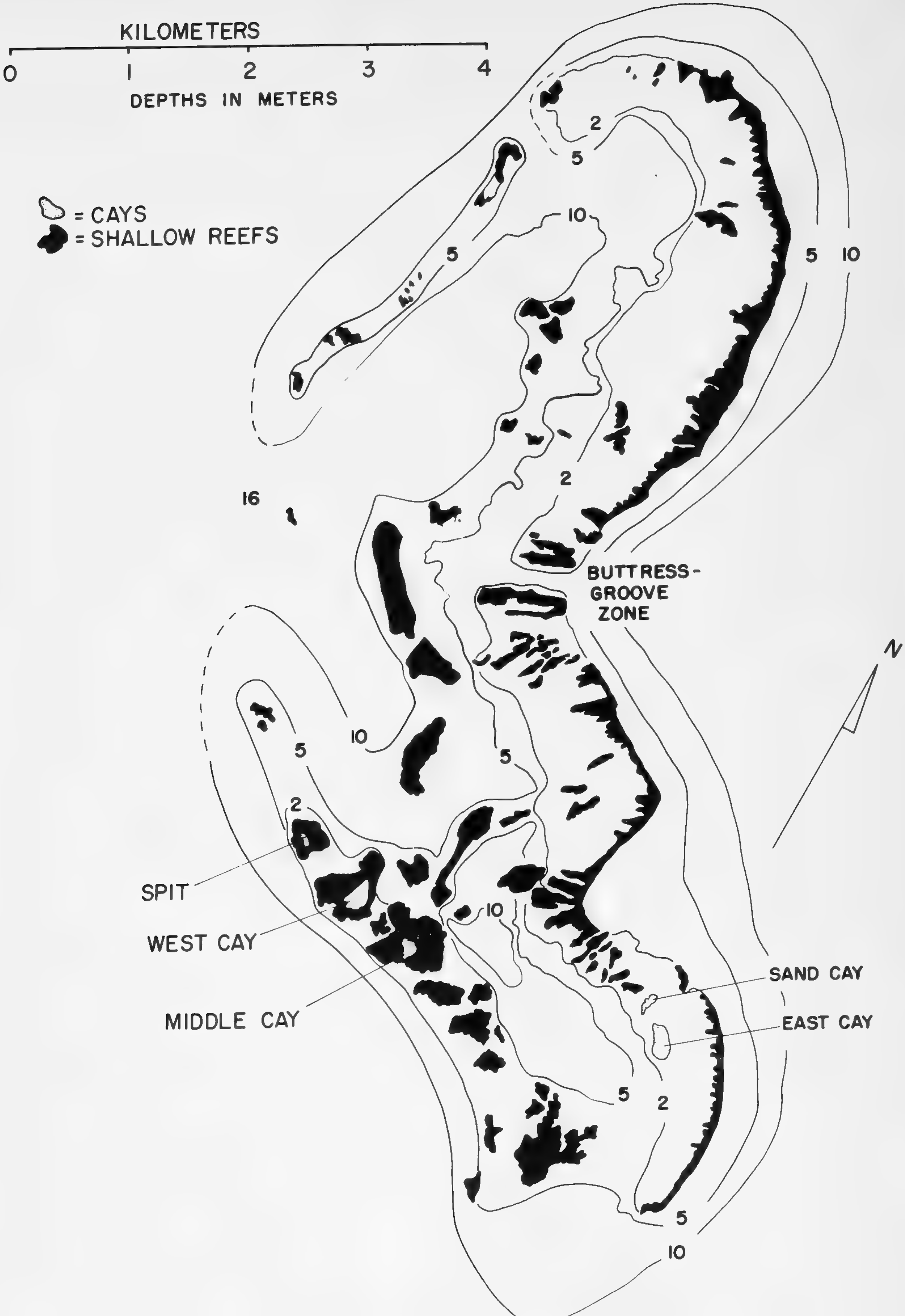


1. Chart of western Caribbean and Central America.

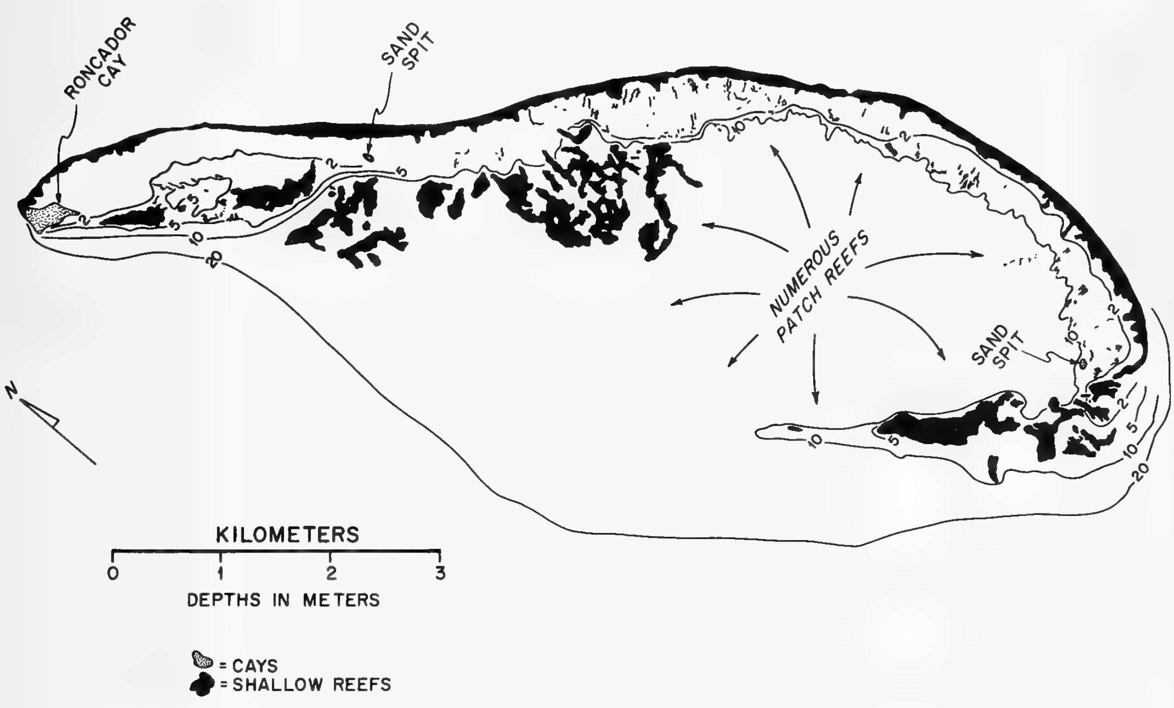


2. Study area chart.

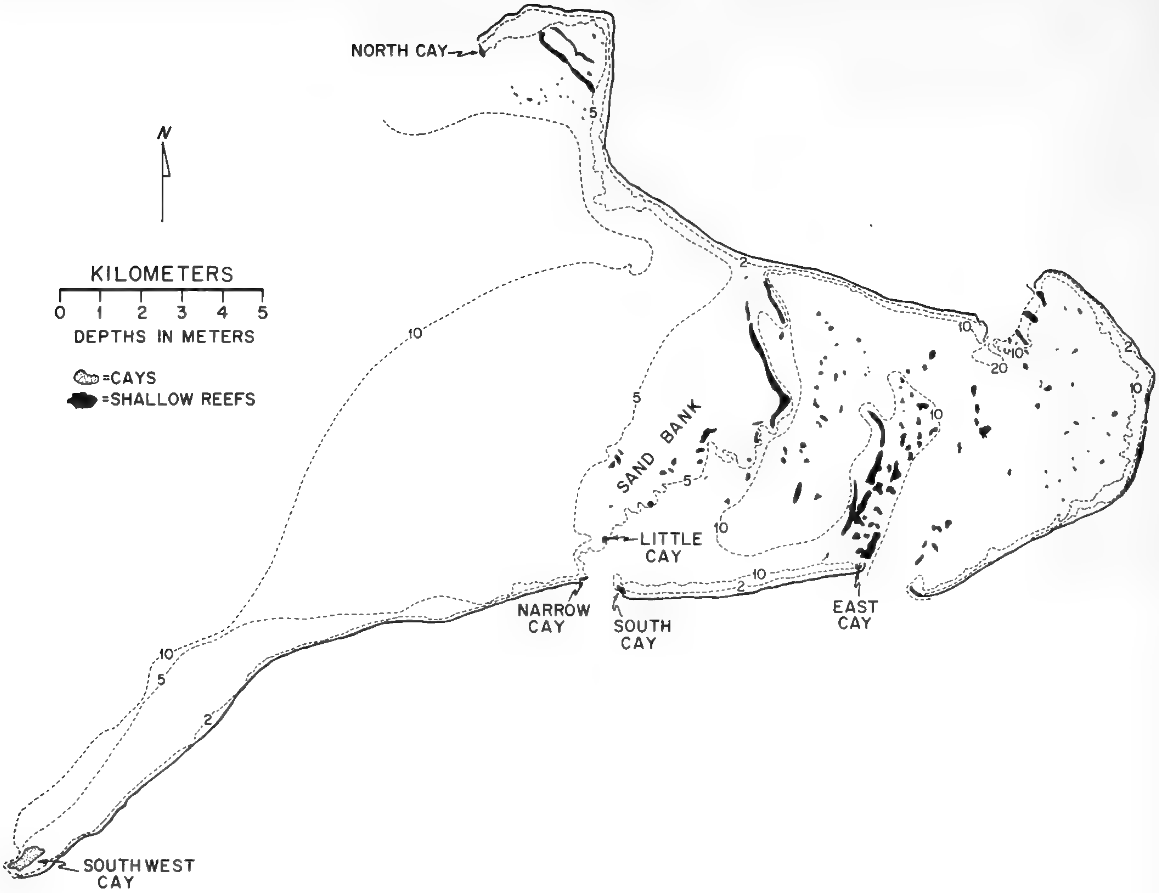


3. Chart of Courtown Cays, based on aerial photographs, H. O. Chart 2077, and observations made during the cruise.

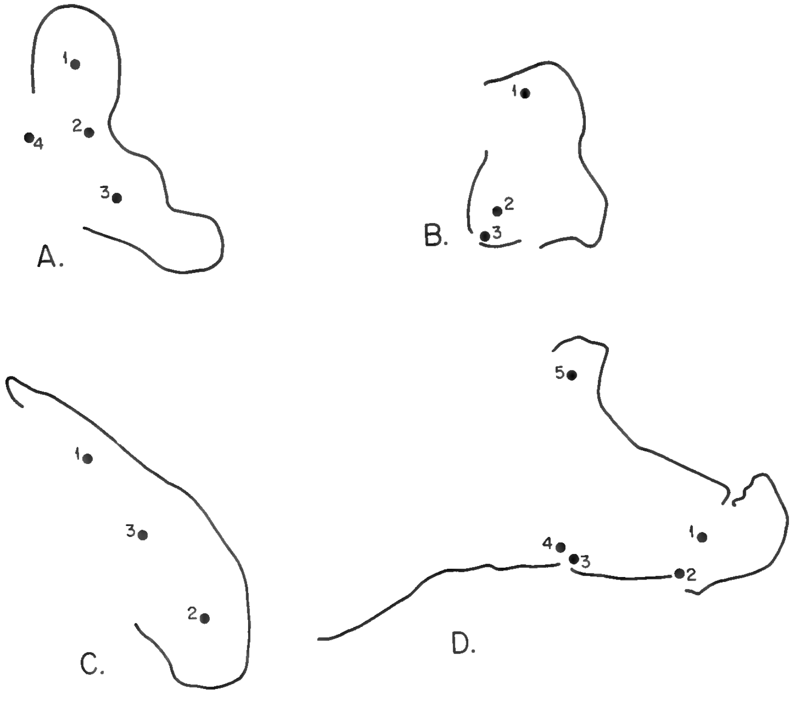
4. Chart of Albuquerque Cays, based on aerial photographs, H. O. Chart 2077, and observations made during the cruise.



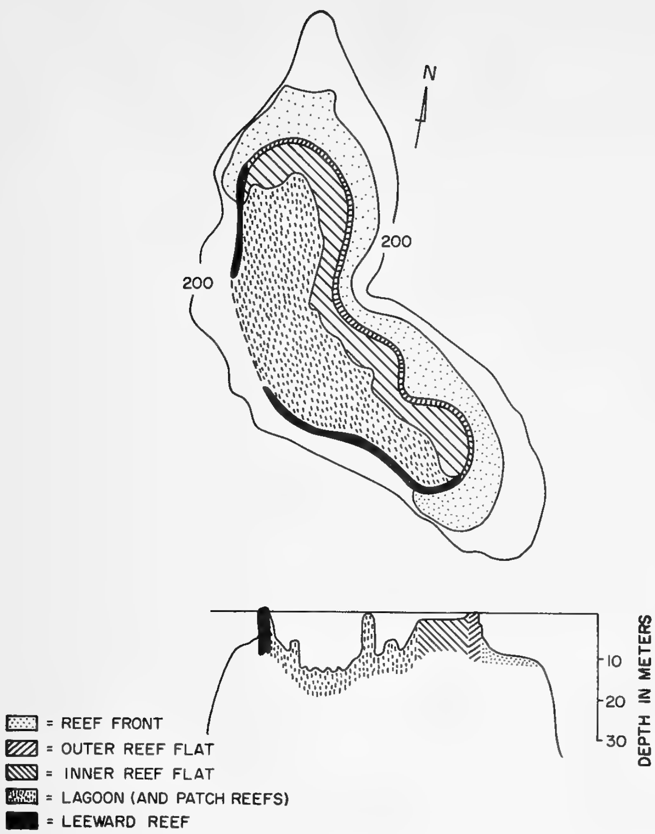
5. Chart of Roncador Bank, based on aerial photographs, H. O. Chart 1374, and observations made during the cruise.



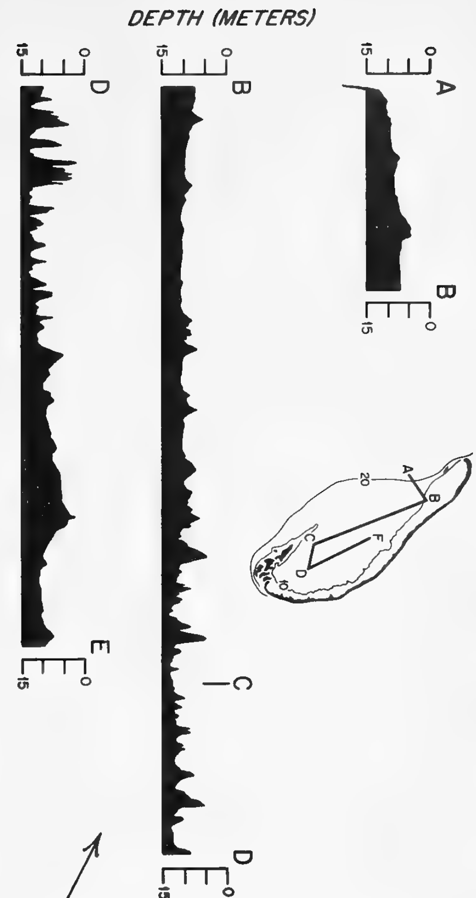
6. Chart of Serrana Bank, based on aerial photographs, H. O. Chart 1374, and observations made during the cruise.



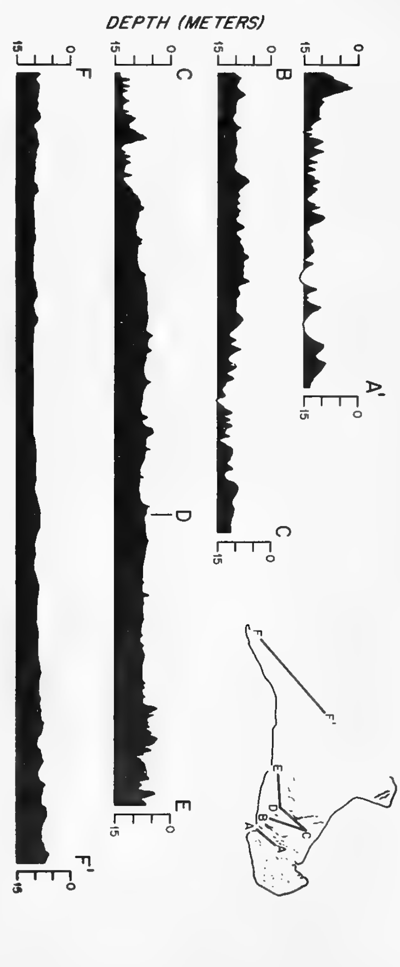
7. Locations of hydrographic stations occupied at Courtown Cays (A), Albuquerque Cays (B), Roncador Bank (C) and Serrana Bank (D).



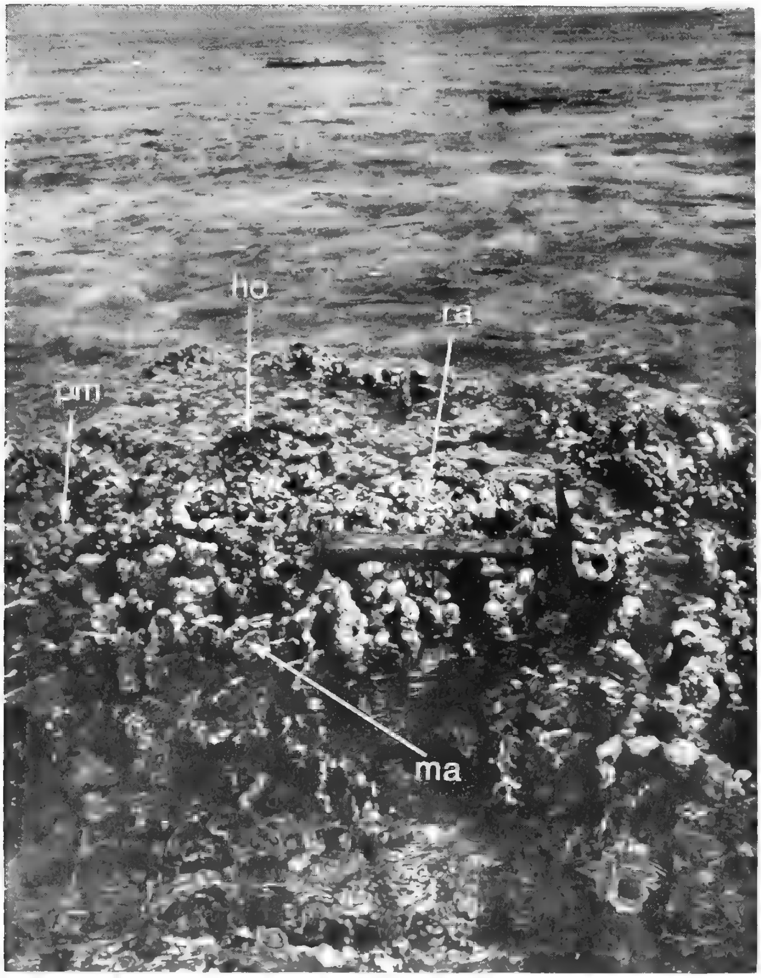
8. Idealized plan and cross sectional views of the ecologic zonations at Courtown Cays. The other atolls have similar zonations.



9. Profiles of the lagoon at Roncador Bank, based on soundings made during the cruise. These profiles depict the great number of patch reefs within the lagoon, and also show the lack of any apparent sill (profile AB).

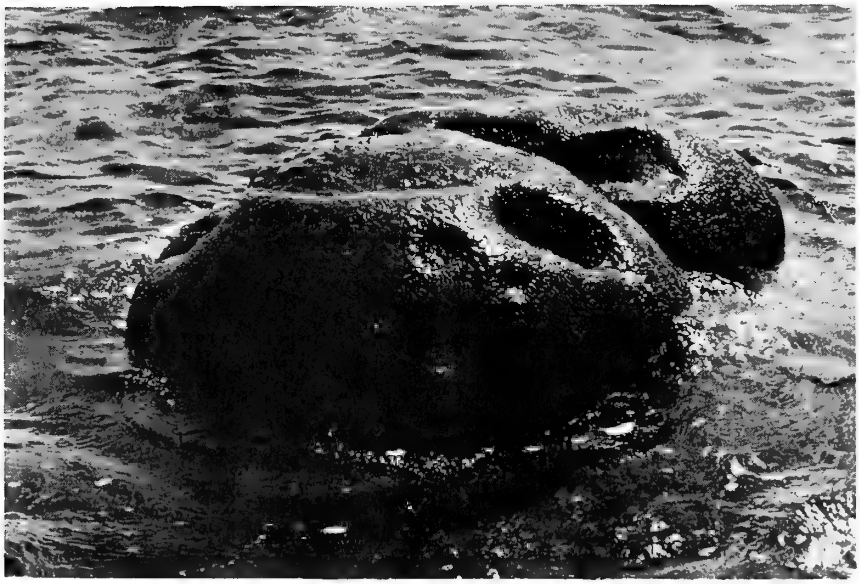


10. Profiles of Serrana Bank lagoon. These profiles show the contrast of the great number of patch reefs in the eastern part of the lagoon, and the relatively flat, shallow lagoon bottom to the west (profile FF').



1. The Millepora zone, composed primarily of the flat hydrocoral Millepora alcicornis (labeled ma in picture), the soft coral Palythoa mammillosa (pm) and encrusting red algae (ra); Halimeda opuntia (ho) is also common.

2. A panoramic photograph of the Millepora zone in the heavy surf zone (left) of the outer windward reef. This picture was taken at Roncador Bank during spring low tides; similar, but somewhat less well-developed colonies are found at the ~~other atolls~~.



3. A large colony of Diploria, located in the Diploria zone on the outer reef, is seen exposed about 1/2 m above low tide. The upper 10 cm of the coral is dead, perhaps reflecting the limit to which. normal waves can bathe it.

4. Depths in the inner reef flat (foreground) are significantly greater than on the outer reef flat (background).

5. At all atolls the majority of lagoon reefs are scattered, low-lying patches. The bottom depth in this photograph is about 13 m; the diver is 5'10" tall.

6. Patch reefs often have an abundance of foliose and pinnacle growth forms of Montastrea annularis, the latter shown in the center of this picture.

7. Bands of beachrock extend windward from East Cay at Courtown Cays, seemingly indicative of the lagoonward migration of the cay. Tall palm trees characterize the vegetation on East Cay. In the background is the wreck of a Colombian ship, awash on the reefs.

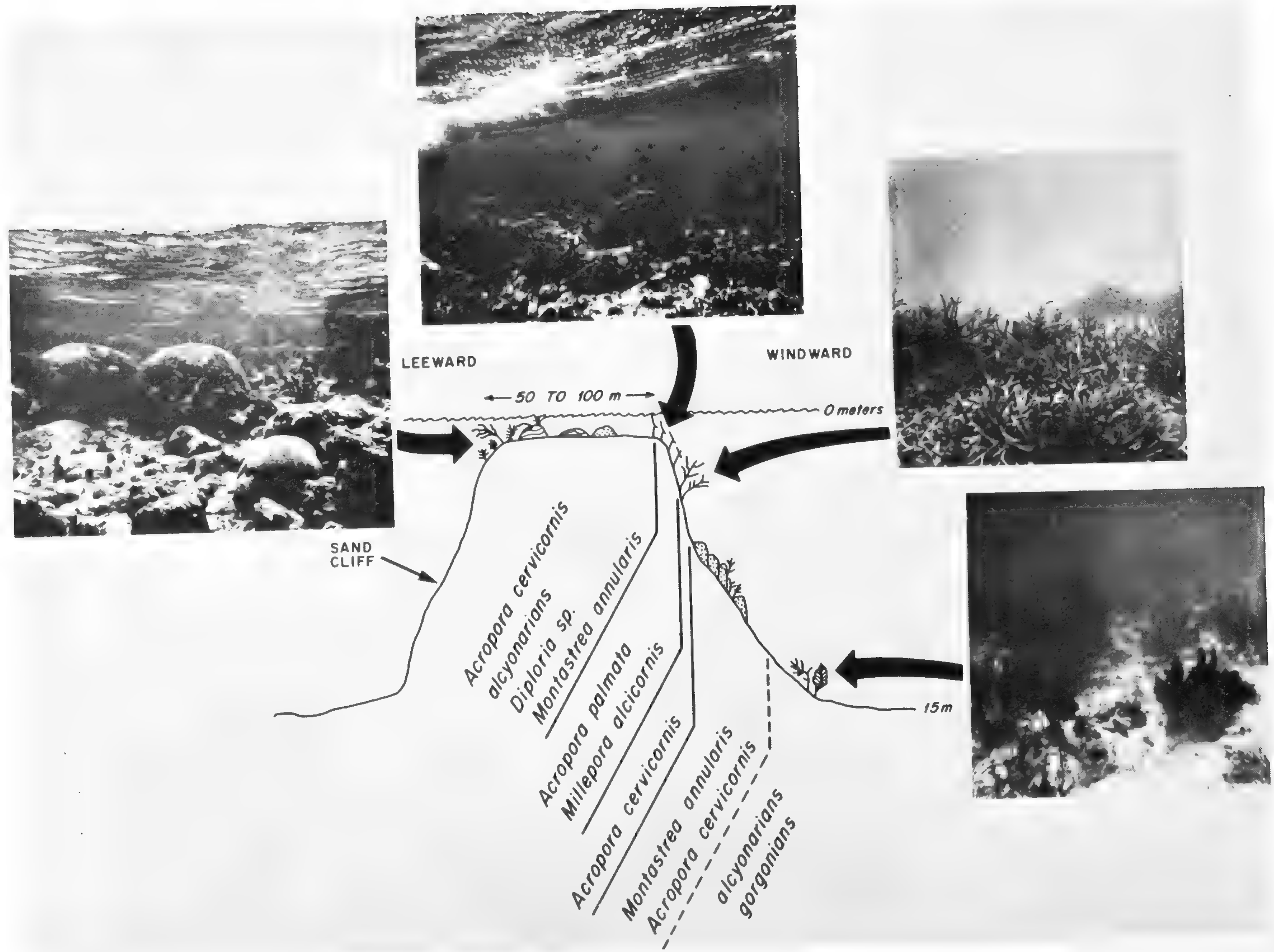
8. Close-up picture of the beachrock bands. Fissures are parallel and perpendicular to the strike of the rock.

9. Elevated beachrock at North Cay, Albuquerque Cays. Recent beach-rock is in the foreground of the picture.

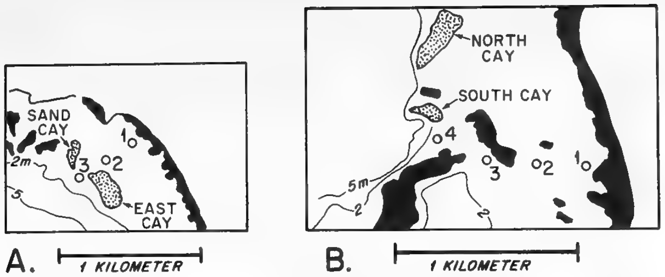
10. Dense _Ficus_ **forest at** South Cay, Albuquerque Cays.

11. Rocks emergent at low tide line the windward rim of the outer reef at Roncador Bank. Roncador Cay is seen in the background.

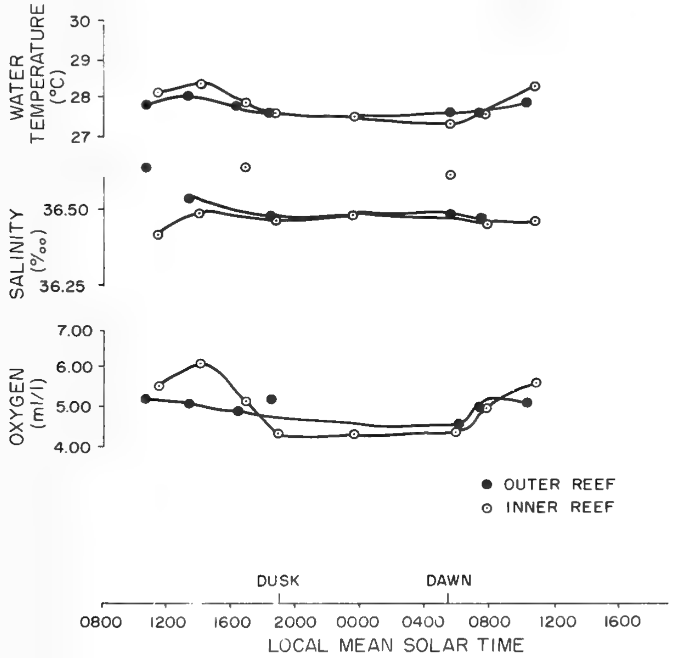
12. Roncador Cay is covered with a rubble of coral heads. Piles of these dead corals were once used as walls.



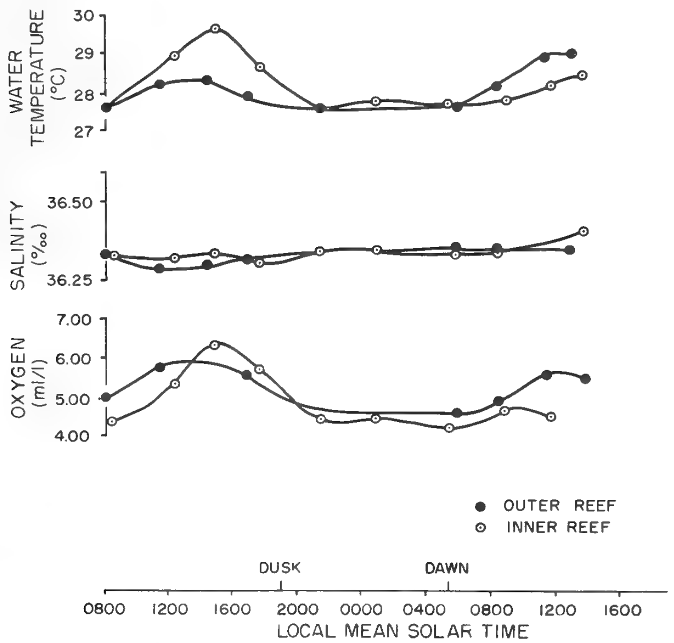
3. A cross-section of a lagoon patch reef at Serrana Bank. The photographs illustrate the various communities that characterize the different depths and environments.



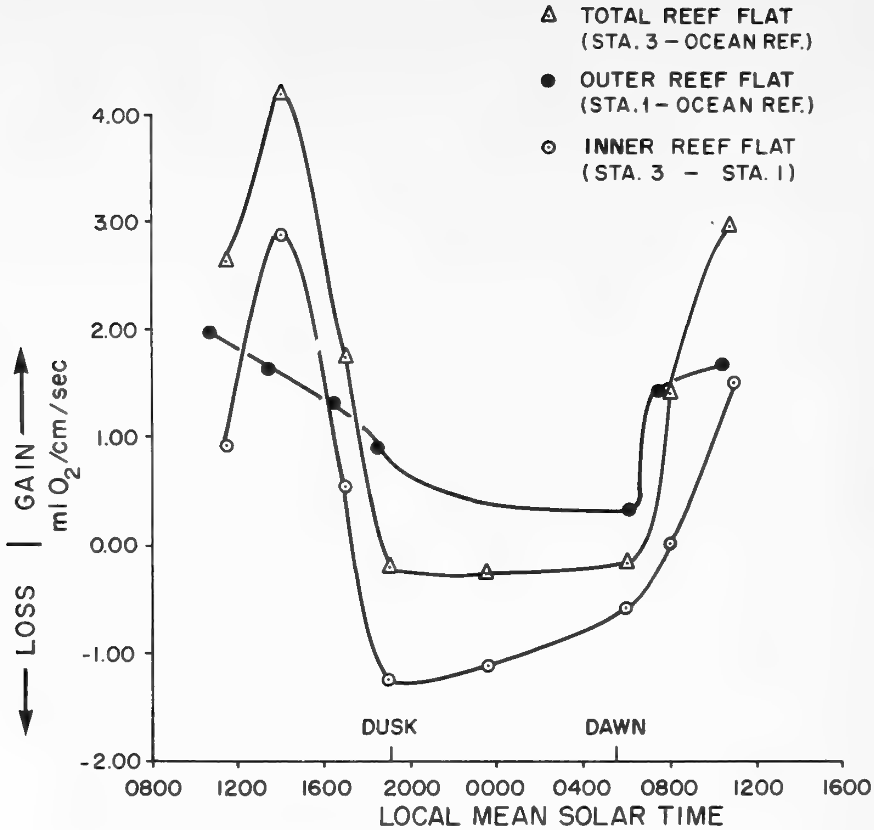
A-1 Locations of reef productivity stations at Courtown and Albuquerque Cays.



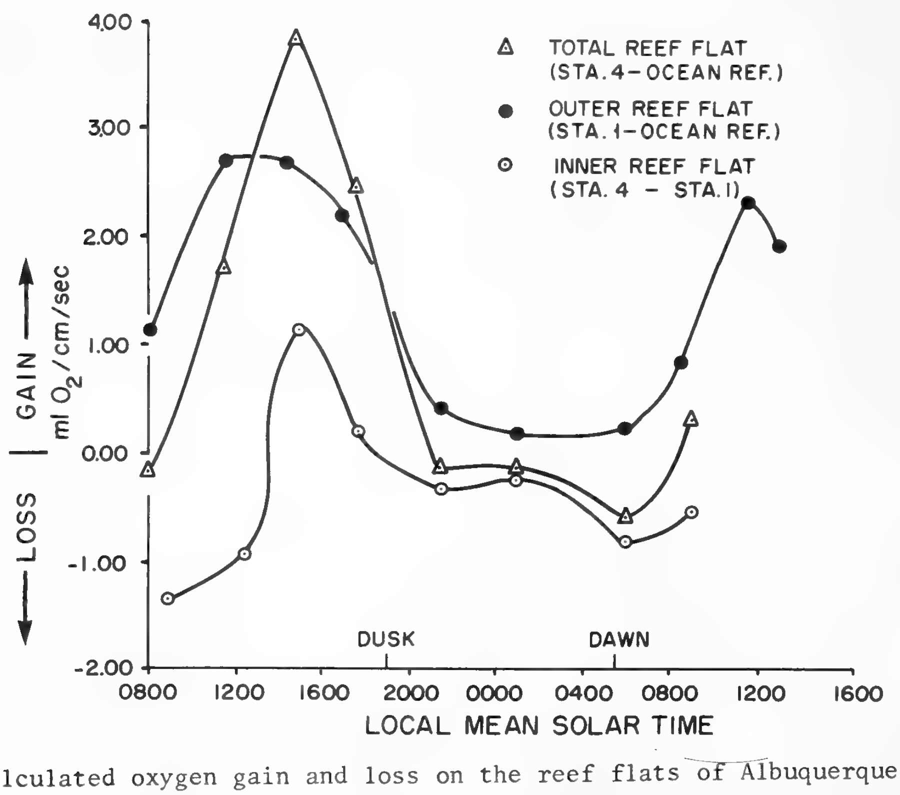
A-2. Time plot of temperature, salinity and oxygen variations on the reef flats of Courtown Cays.



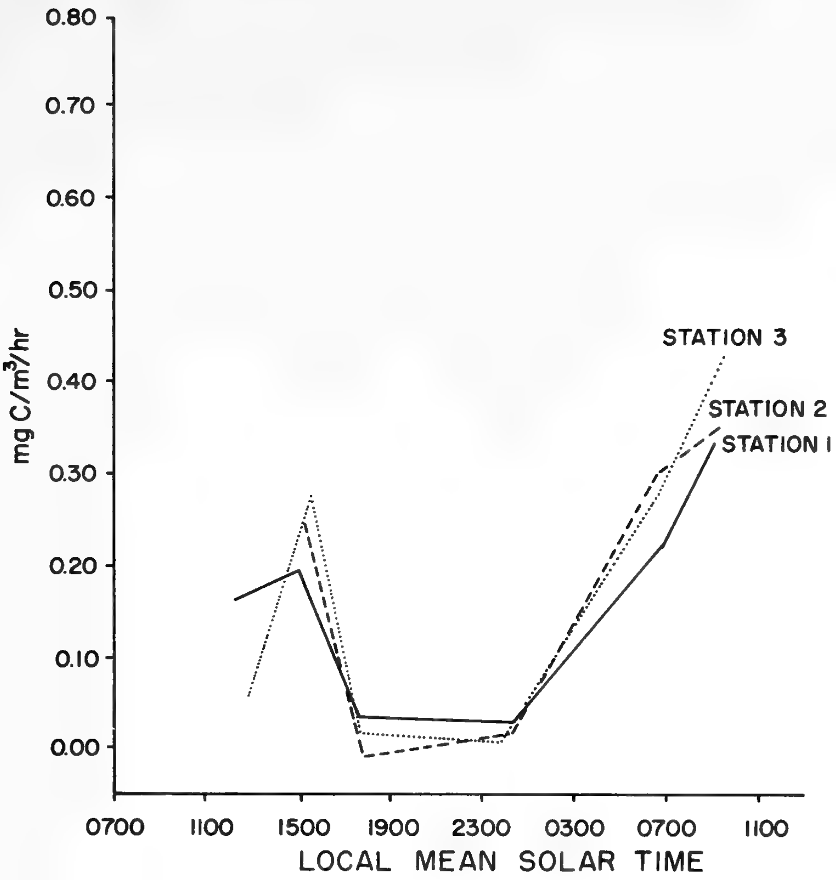
A-3. Time plot of temperature, salinity and oxygen variations on the reef flats of Albuquerque Cays.



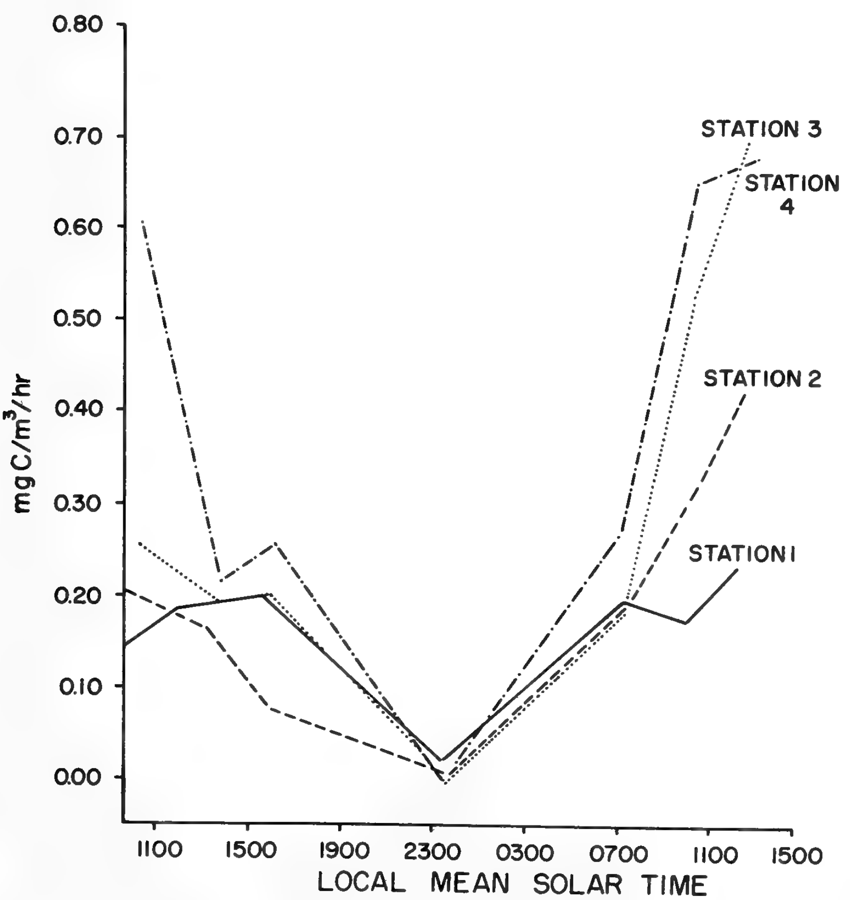
A-4. Calculated oxygen gain and loss on the reef flats of Courtown Cays.



A-5. Calculated oxygen gain and loss on the reef flats of Albuquerque Cays.



A-6. Carbon fixation rates across the windward reef flat of Courtown Cays.



A-7. Carbon fixation rates across the windward reef flat of Albuquerque Cays.

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NO. 130

A BOTANICAL DESCRIPTION OF BIG PELICAN CAY, A LITTLE KNOWN ISLAND OFF THE SOUTH COAST OF JAMAICA

by C. D. Adams

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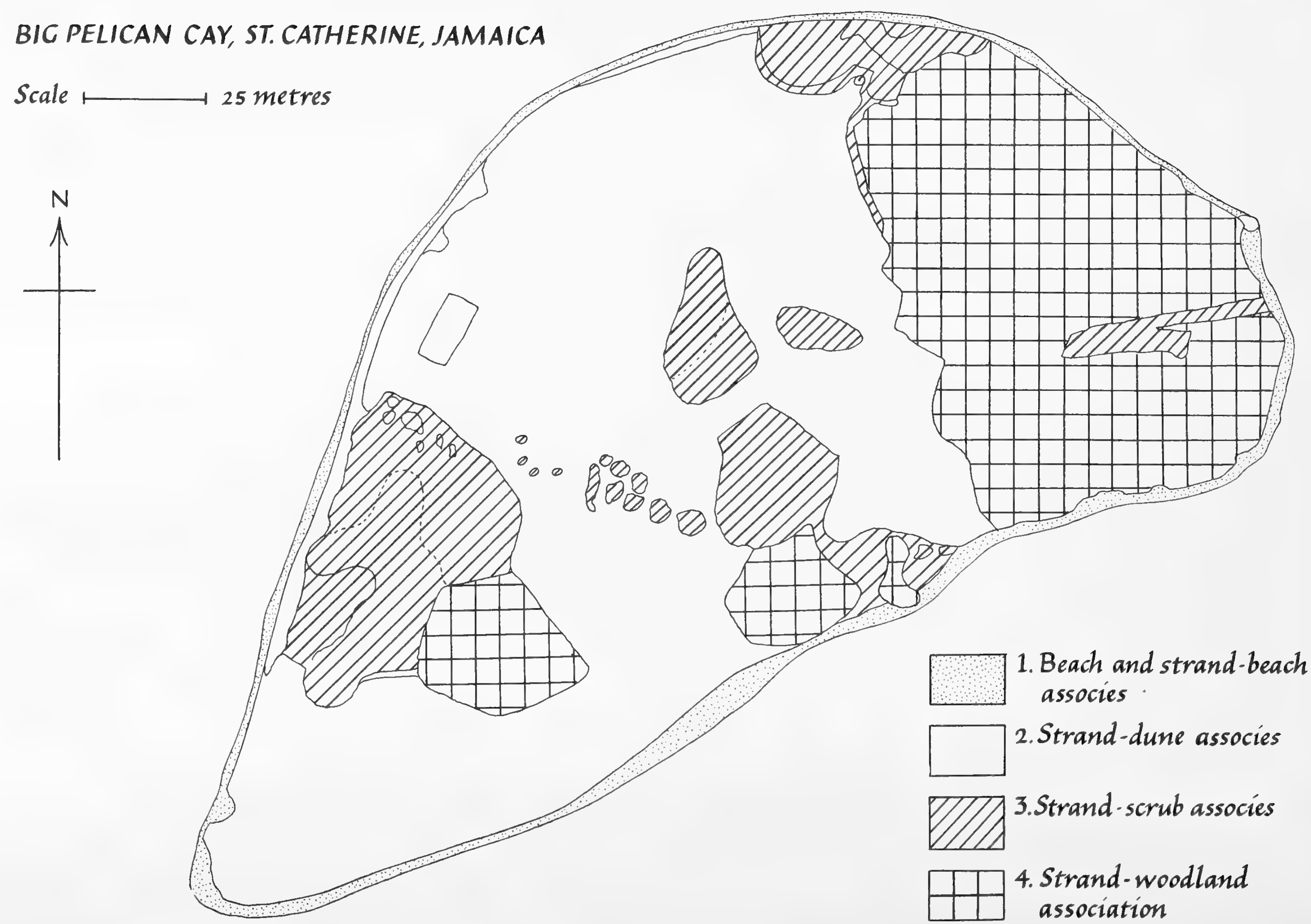
BIG PELICAN CAY, ST. CATHERINE, JAMAICA
Scale 25 metres
N
1. Beach and strand-beach associes
2. Strand-dune associes
3. Strand-scrub associes
4. Strand-woodland association

A BOTANICAL DESCRIPTION OF BIG PELICAN CAY, A LITTLE KNOWN ISLAND OFF THE SOUTH COAST OF JAMAICA

by C. D. Adams [1]

Abstract

Big Pelican Cay is an island of 5-1/2 acres composed entirely of coral sand and lying about three miles off the south coast of Jamaica. The island has a natural flora of 44 species of vascular plants comprising a vegetation of several seral units, comparable with units described for the Florida Keys, and a woodland dominated by *Conocarpus erectus*. Within a small area the vegetation reaches a high level of complexity and includes not only common tropical seashore plants of more or less xeromorphic type but, within the woodland, herbs, shrubs and trees of more mesophytic character. The vegetation is unusual in that not only is the climax dominated by *Conocarpus*, which is elsewhere a transitional or marginal species, but it lacks any significant mangrove community. This cay exemplifies within the West Indian phytogeographical region, the vegetation of a sand cay.

Acknowledgements

All information given in this account other than that obtained from cited references or acknowledged here, is the result of the author's observations during February/March 1963 and October 1967. The cooperation of Dr. Walter Carter, formerly of F.A.O., and of Mr. Michael Campbell of Kingston, whom I accompanied on visits to the island, is gratefully acknowledged. I am also grateful to Mr. Richard Wiczens, lately of the Jamaican Survey Department, who arranged for me to have the use of an aerial photograph from which Figure 1 was drawn, and to Mr. R. A. Gardiner of the Royal Geographical Society, for answering inquiries about other maps. Mr. D. O. Vickers, Director of the Jamaican Meteorological Service provided information about windspeeds.

Position and general description of Big Pelican Cay

Big Pelican Cay is an island situated 2.9 miles SSW of Coleman's Bay off the southernmost tip of the Hellshire Hills in the parish of St. Catherine, Jamaica. Owing to its distance from the mainland, this cay does not appear on the topographical survey maps of Jamaica (1:50,000 edition), but its position is indicated on the maps showing the Portland Bight Cays accompanying the papers of Steers, Chapman *et al.* (1944) and Chapman (1944). Admiralty Chart No. 457 (1954) also

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shows the cay on a rather small scale. The island is one of few scattered along the almost continuous arc of reef extending north-eastwards from Portland Point.

The area of the cay above sea-level is 22,650 square meters (5.6 acres) and at no point is it more than 1.6 meters (5.4 feet) above sea-level. The oldest part is probably at the eastern end and the island seems to be increasing in a westward direction by deposition of calcareous sand largely composed of fragments of *Halimeda opuntia* and shells. This sand forms an undulating surface to the whole island where there is vegetation and there are no outcrops of smashed coral as at Lime Cay. Lime Cay is one of the well-known Port Royal Cays outside Kingston harbor, and is almost the same size as Pelican Cay. While Asprey and Robbins (1953) refer to Lime Cay as consisting of "sand containing a high proportion of the remains of the lime-encrusting *Halimeda opuntia*" without qualification, this is only true of its leeward aspects. Steers (1940) clearly distinguishes between *shingle* cays composed largely of exposed coarse broken coral material of which Lime Cay is an example, and *sand* cays such as Pelican Cay where even at the vulnerable windward end, the island consists uniformly of sand. The 1939 Cambridge expedition made a very brief survey of this cay and no detailed botanical description was included in their publications.

Climatic data are lacking for any of these cays but it is certain that one of the most important factors determining their shape and physical evolution, as well as to some extent, the character of their vegetation, is the consistent easterly breeze. Wave action and salt spray depend on this wind which at certain times of the year, especially in June and July, blows at strengths up to Force 5 for several daylight hours. The windward southern and eastern aspects are protected by a shallow lagoon several hundred meters broad outside which the principal reef lies. Wave action on these beaches in normal weather amounts to little more than a gentle lapping, but salt spray from the reef is often evident.

Vegetation of Pelican Cay

The four main communities described by Davis (J. H. Davis, 1942) for the Florida Keys can be recognized on Pelican Cay and account for all the communities which occur there. These are 1. the Strand-beach associes; 2. the Strand-dune associes; 3. the Strand-scrub associes and 4. the Strand-woodland association (the map, Figure 1, shows their distribution).

1. The Strand-beach Associes

The pioneer vegetation occurring almost all around the island in a narrow marginal zone is not uniform and has three more or less distinct facies depending on the other communities with which it happens to be in contact:

a) Where the beach is backed directly by the strand-dune associes and woodland or thicket is absent, the pioneer flora forms a distinct zone with several recognizable sub-zones. The first colonizers, of low cover value, are *Sesuvium portulacastrum* and *Ipomoea pes-caprae*, the former being constantly present and more abundant.

On the sharply rising upper beach this open sub-zone is replaced abruptly by Philoxerus vermicularis which then by less abrupt and intermingling stages gives way through sub-zones dominated by Euphorbia mesembrianthemifolia and then Canavalia maritima to the more stable dune community of almost pure Sporobolus virginicus on the higher better drained parts and Paspalum distichum with Sporobolus on the lower.

This series is well shown along the western half of the southern shore. The most obvious irregularities are to be found towards the extreme western tip of the cay where the common primary invaders may be replaced locally by Paspalum distichum and other forward dune species, namely Euphorbia mesembrianthemifolia, Canavalia maritima and Cenchrus tribuloides. All these species, except Euphorbia mesembrianthemifolia, have trailing branches and are dicotyledons with fleshy leaves or are grasses. Plants of Euphorbia mesembrianthemifolia are usually bushy and may rise to 45 cm (18 in.) tall. All the other species in the typical exposed pioneer to forward dune series are of lower stature, but Philoxerus tends to have ascending form even in exposed places.

b) Where the beach is backed directly by the strand-scrub cactus thicket, as along the northwest facing shore, the upper beach is eroded and frequently has a distinct step about two feet high. Below the shelf so formed only a few trailing stems of Sesuvium occur. On the top of this shelf, which is composed of deep fine sand, there is a thin cover of the more erect bushy but still fleshy leaved herbaceous species of which Cakile lanceolata, Philoxerus vermicularis, Euphorbia mesembrianthemifolia and Stachytarpheta jamaicensis are the most conspicuous.

c) Around the eastern end of the island woodland extends to within a meter of high-water and thus only a very narrow zone of herbaceous pioneer vegetation exists there. This consists of often isolated rather pure stands of Cakile lanceolata, Sesuvium portulacastrum, Alternanthera halimifolia, Philoxerus vermicularis and Paspalum distichum. Owing to the shelter provided by the nearby trees of Conocarpus erectus, these herbaceous plants grow taller than elsewhere on the island and some of them even tend to scramble among the lower branches of the trees. The only species which is conspicuous in all three facies of the pioneer zone is Sesuvium portulacastrum.

Species of the Strand-beach Associes	Frequency [1/]
Alternanthera halimifolia (Lam.) Standl.	o
Atriplex pentandra (Jacq.) Standl.	l
Cakile lanceolata (Willd.) O. E. Schulz	f
Canavalia maritima (Aubl.) Urb.	o
Cenchrus tribuloides L.	l

[1/] Explanation of abbreviations: o, occasional; l, local; f, frequent; vr, very rare; f-a, frequent to abundant; a, abundant; o-r, occasional to rare; ld, locally dominant.

Colubrina asiatica (L.) Brongn.	vr
Euphorbia mesembrianthemifolia Jacq. (E. buxifolia Sw.)	f
Ipomoea pes-caprae (L.) R. Br. ssp. brasiliensis (L.) Ooststr.	l
Paspalum distichum L. (P. vaginatum Sw.)	l
Philoxerus vermicularis (L.) Beauv.	f-a
Rhizophora mangle L. (seedlings or saplings only)	vr
Sesuvium portulacastrum (L.) L.	a
Sporobolus virginicus (L.) Kunth	l
Stachytarpheta jamaicensis (L.) Vahl	o-r

2. The Strand-dune Associes

This vegetation comprises the low grassland community occupying the extensive depression in the middle of the island and also much of the western half. At various points it abuts on to all the other communities and is the only one which is continuous at the present time. Its seral status is belied by the sharp boundaries existing between the grassland and the thickets or woodlands with which it is in contact. This apparently stable feature may be associated with a history of goat grazing (removed in the latter part of 1962) and possibly fire. On the other hand at certain places isolated or gregarious shrubs of *Morinda royoc*, *Capparis flexuosa* and *Caesalpinia bonduc* in young stages of growth indicate a developmental trend towards thicket. There is also probably a slow frontal encroachment upon the grassland by the larger continuous areas of *Opuntia dillenii* which might proceed in opposition to a grazing factor but be stabilized by fire. As the *Opuntia* scrub is distributed more towards slightly higher ground a drainage or soil salinity factor might also be involved in determining the position of the boundary with the grassland.

The grassland varies in cover value to a considerable extent, being thinnest towards the southwest, where it is patchily dominated by *Paspalum*, and is in continuous contact with the strand-beach associes. Cover approaches completeness along the boundary with the *Conocarpus* woodland in the northeast. It is fairly certain that the most dense aspects of the *Sporobolus* grassland would burn with a hot damaging fire after a long period of drought, but the indication from the amount of living and dead plant material which has accumulated is that this does not happen frequently.

In the extreme northern part of the island the *Sporobolus* grassland reaches the eroded beach and a little west of that there is a relatively pure and extensive stand of *Panicum maximum*.

As a result of human activity along the middle region of the northwestern shore and the presence of a small house, several cultivated plants and weeds occur independently of the more natural dune grassland.

Species of the Strand-dune Associes		Frequency
a) Dune grassland species		
Caesalpinia bonduc (L.) Roxb.	woody invader	o
Canavalia maritima (Aubl.) Urb.	trailing invader	f-a
Capparis flexuosa (L.) L.	woody invader	o
Cyperus planifolius L. C. Rich	tight-headed rufous variant	o
Echites umbellata Jacq.		l
Morinda royoc L.	woody invader	l
Panicum maximum Jacq.	north side only	ld
Paspalum distichum L.	southwest area	ld
Sporobolus virginicus (L.) Kunth		d
Tribulus cistoides L.		f
Turnera ulmifolia L.	Bushy hirsute variant	o
b) Cultivated plants and weeds		
Agave sisalana Perrine		l
Boerhavia coccinea Mill.	also in nearby dune	o
Casuarina equisetifolia J.R. & G. Forst.		1 plant
Cenchrus brownii Roem. & Schult.		r
Cocos nucifera L.	seedlings and 6 plants *	
Delonix regia (Boj. ex Hook.) Raf.		1 plant
Nerium oleander L.		1 plant
Portulaca oleracea L.	also in nearby dune	f

* All existing specimens of Cocos were removed in 1963 in preparation for an experimental planting of seedlings in the north-central grassland area.

3. The Strand-scrub Associes

This community is the most patchy and dissected vegetation represented on the island. It also lacks uniformity in the occurrence within the patches of gregarious shrubby species surrounded by Opuntia dillenii. All examples of scrub have boundaries with the grassland and most of the larger areas also have boundaries with Conocarpus woodland. The disposition of scrub in relation to woodland is consistently towards the northwest or leeward side.

Undoubtedly the strand-scrub associes is the most obviously seral and unstable vegetation of Pelican Cay. As plants of Opuntia dillenii are almost everywhere contiguous in each patch of scrub and form narrow hedges around the larger clumps of shrubs, it is not possible for man or grazing animals to enter. Being to the leeward of woodland these areas are least likely to be affected by wind or salt spray and except at the margins would not be damaged by fire. The community could therefore be expected to follow through a sequence of natural stages leading to woodland.

At the northern end of the large Conocarpus woodland there is a clear indication of the replacement of Opuntia by Suriana maritima. Here a substantially pure stand of Suriana rising to 2.5 meters (about eight feet), forms a localized thicket and this species is evidently competing successfully with the cactus in that there are dead or dying plants of the latter within the thicket. Nearby a narrow continuation

of the cactus fringe is separated by a higher hedge of Capparis flexuosa between it and the woodland. The same woody species, as well as Cordia sebestena, occur in clumps in the large scrub area in the western part of the island. Here enclosed by cactus, and again probably competing successfully with it are Cordia sebestena to 3.5 meters (about 12 feet), Capparis flexuosa to 2.5 meters (about eight feet) and Suriana maritima to 1.5 meters (five feet). At one point only was it evident that Conocarpus was invading the cactus scrub directly.

It is noteworthy that everywhere associated with Opuntia dillenii in the more open scrub are numerous herbaceous or woody scramblers and vines. These tend to cover and possibly suppress the cactus. The sequence of events in the succession is thus:

1) Opuntia dillenii and a few shrubby species invade the dune. The latter would possibly succumb to fire and grazing, the cactus only to fire and only then where directly in contact with combustible material such as dead Sporobolus;

2) the cactus is weakened or suppressed by vines such as Canavalia maritima, Ipomoea tuba and Echites umbellata which thereby create openings within the cactus area now protected from grazing, fire and wind for,

3) the establishment of erect shrubs, Suriana maritima, Capparis flexuosa and Cordia sebestena. Thereafter the field layer is eliminated by shade and

4) Conocarpus eventually takes over.

Species of the Strand-scrub Associes		Frequency
Caesalpinia bonduc (L.) Roxb.	prickly scrambler	o
Canavalia maritima (Aubl.) Urb.	twiner	f
Capparis flexuosa (L.) L.	straggling shrub	o-f
Cordia sebestena L.	shrub or small tree	l
Echites umbellata Jacq.	twiner	r
Ipomoea tuba (Schlecht.) G. Don	twiner	f-a
Morinda royoc L.	twiner	o
Opuntia dillenii (Ker-Gawl.) Haw.		d
Suriana maritima L.	erect shrub	f
Tribulus cistoides L.	trailing herb	r

4. The Strand-woodland Association

The most advanced and stable community on Pelican Cay, and that which must be regarded as the local climax, is the woodland dominated by Conocarpus erectus. This woodland occupies one quarter of the total area at the eastern end and occurs also in two smaller patches in the south-center and southwest. The trees in this woodland are rather evenly spaced, being on an average about four meters (13 feet) apart, rise to a general height of about six meters (20 feet) with occasional taller examples and form a nearly closed canopy. A few other species, numerically insignificant in the vegetation, grow to the same dimensions as the Conocarpus and include Bursera simaruba, Metopium brownei and Citharexylum fruticosum. Around the margins of the woodland the Conocarpus trees tend to be of lower stature except along the northern shore. This is evidently due to wind in the southerly and easterly margins but may be due to youth along the boundary with the dune. The

trees seem to be invading the dune slowly and are mixed here with the shrubby *Capparis flexuosa*.

Within the woodland the old trunks of *Conocarpus*, greyish-brown in color and deeply long- and criss-cross-fissured, are mainly tilted and gnarled so that some of the larger branches reach the ground. Girths of these trees range from 89 cm (35 in.) to 140 cm (55 in.). There is a subsidiary thinly dispersed stratum of shrubs and small trees with *Capparis flexuosa*, the commonest species, occasionally reaching tree stature. Although the leaves of species of *Capparis* vary greatly in shape, being narrowly linear on young saplings and ranging to broadly oblong (*C. flexuosa*) or lanceolate (*C. ferruginea*), the two species are easily distinguished by the leaves of the former being entirely glabrous and those of the latter having stellate scales on the abaxial surface.

The western boundary of the main area of woodland is in contact with the dune grassland at the southern part and with scrub at the northern part where a narrow strip of *Opuntia dillenii* extends between the woodland and dune. The margin of the woodland along this boundary comprises younger plants of *Conocarpus* mixed with *Capparis flexuosa* and *C. ferruginea*. The herbaceous species *Rivina humilis* and *Turnera ulmifolia* are also present. Exposed more open and better illuminated parts of the woodland have a few plants of the climbers *Ipomoea tuba* and *Canavalia maritima* which may be relict from the scrub associes.

Along the eastern seashore trees come close to the beach, being separated from it by a narrow mixed herbaceous littoral zone (see 1, c).

There is no obvious indication of edaphic differences determining the boundary between the woodland and the dune but the woodland itself produces a deep leaf litter and superficial humus in the interior where there is very little herbaceous vegetation. It is noteworthy that *Cyperus planifolius* and *Turnera ulmifolia* occur there in forms distinct from those which these species adopt in the grassland. The woodland forms have a much more mesophytic appearance than their counterparts outside the woodland and, combined with the presence of *Rivina humilis* and a well established patch of *Wedelia trilobata*, indicate the dependence of these herbs on the shade and lower temperatures of the woodland interior.

Species of the Strand-woodland Association		Frequency
Alternanthera halimifolia (Lam.) Standl.	better lit seaward margins	l
Avicennia germinans (L.) L.	seashore margins	r & l
Bursera simaruba (L.) Sarg.		r
Caesalpinia bonduc (L.) Roxb.	marginal climber	r
Canavalia maritima (Aubl.) Urb.	marginal climber	r
Capparis ferruginea L.		o
Capparis flexuosa (L.) L.		f
Citharexylum fruticosum L.		vr
Coccothrinax jamaicensis R.W. Read (2 plants)		r
Conocarpus erectus L.		d

Cyperus planifolius L.C. Rich	diffuse-headed green variant	f
Gossypium hirsutum L. var. marie-galante (Watt) J.B. Hutch.	(1 plant)	vr
Ipomoea tuba (Schlecht.) G. Don	marginal climber	o
Laguncularia racemosa (L.) Gaertn. f.	seashore margins	r & l
Metopium brownei (Jacq.) Urb.		o
Torrubia obtusata (Jacq.) Britton	(1 plant)	vr
Rivina humilis L.		a
Solanum bahamense L.		r
Trichostigma octandrum (L.) H. Walt.	interior climber	r
Turnera ulmifolia L.	attenuated glabrescent variant	f
Vallesia antillana Woodson	(1 plant)	vr
Wedelia trilobata (L.) Hitchc.		l

Representation of Mangrove Species on Pelican Cay

While all three of the commonly occurring American species of mangroves have been reported from Pelican Cay they have failed to establish themselves sufficiently to form a community or to contribute significantly to any of the communities already described. Avicennia germinans is represented by three plants; one old tree mentioned by Steers (1940), which had reached quite large dimensions grew at the most easterly point of the island but was felled in about 1964. Other younger plants occur with a few plants of Laguncularia along the southern margins of the Conocarpus woodland.

Steers (1940) and party in 1939 reported that "near the southern end of the windward side at least four seedlings of Rhizophora have taken root on the reef near the cay." One seedling of Rhizophora mangle was seen rooted in the shallow lagoon about two meters off the western shore in 1963. This plant was not seen in 1967 but five young plants have since become established off the southern shore. Two of these are saplings about one meter tall. It is obvious that many seedlings of this species must be carried to the cay from the east but although some of them root on the reef or in the lagoon they seem to be transient and none has survived there to make a stable unit of mangrove vegetation.

The contrast between the negligible contribution of mangroves to the vegetation of this island and to that of other islands where mangroves form distinct communities of their own, emphasizes one of the main differences between this sand cay and the shingle cay, exemplified by Lime Cay.

Affinities of the Flora

Common widespread tropical littoral species comprise the early seral stages as would be expected. Among the woody components of the more stable phases are West Indian plants of more limited distribution e.g. Suriana maritima, Cordia sebestena and Capparis ferruginea. It is among this group of life forms, the shrubs and trees, that the most significant comparisons in floristic composition can be made between the islands and adjacent mainland formations.

Pelican Cay is nearest to the southern Hellshire Hills which support a vegetation of thicket and woodland on limestone. This area is calcareous and rocky or sandy to the sea.

Several non-maritime species are common to the Hellshire Hills thickets and Pelican Cay; all have baccate or drupaceous fruits and have not been reported from Lime Cay. These include:

Bursera simaruba
Citharexylum fruticosum
Coccothrinax jamaicensis
Metopium brownei
Solanum bahamense
Torrubia obtusata
Trichostigma octandrum
Vallesia antillana

For comparison Lime Cay, which is close to the shingle, pebble and non-calcareous sand spit known as Palisadoes, has the following species in common with Palisadoes which are absent from Pelican Cay:

<u>Mangroves</u>

Avicennia germinans forming communities
Rhizophora mangle " "
Languncularia racemosa " "

<u>Non-mangroves</u>

Acacia tortuosa
Batis maritima
Cassia emarginata
Coccoloba uvifera
Alteramnus lucidus (<u>Gymnanthes</u> <u>lucida</u>)
Lemaireocereus hystrix
Piscidia piscipula
Pithecellobium unguis-cati
Stigmaphyllon emarginatum
Thespesia populnea

These non-mangroves are all species of some importance in Jamaican, if not West Indian, coastal formations and it is remarkable that they do not occur on Pelican Cay. The fruits are mostly dry and quite different from those of the plants in the Pelican Cay list. It is possible that fruit-eating birds have been responsible for a relatively greater contribution to the Pelican Cay flora than to the plant colonisation of Lime Cay. Pelican Cay is much farther than Lime Cay from the mainland and it is less frequently visited by man. Thus differences can be attributed to proximity and opportunity to some extent, but it is believed that these differences also reflect an ecological distinction resulting from the <u>sand</u> and <u>shingle</u> structure recognized by Steers. These two cays each have 44 species of vascular plants but only 24 species in common. Pelican Cay has a more mesophytic aspect than Lime Cay, emphasized by the absence of both xeromorphic woody legumes and halophytic mangroves. Both islands lack epiphytes.

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Plate 1. South shore and southeast tip. Pioneer zone on beach (Sesuvium) backed by Sporobolus and Canavalia. Conocarpus woodland at eastern end separated from grassland by thicket in middle distance. Note absence of offshore plants of Rhizophora (March 1963).

Plate 2. Southeast shore and tip. Conocarpus woodland in contact with Sesuvium at left. Note five saplings of Rhizophora offshore (October 1967). The reef is just below the horizon.

Plate 3. Boundary of *Sporobolus* grassland and thicket near the north-central part of the island. *Sporobolus* and *Canavalia* in left foreground. Hedge of *Opuntia* separates grassland from *Suriana* behind.

Plate 4. Typical old tree of *Conocarpus* in woodland. Note saplings of *Conocarpus* and solitary plant of *Opuntia* (in lower left corner) in otherwise open field layer.

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POST-HURRICANE CHANGES ON THE BRITISH HONDURAS REEFS AND CAYS: RE-SURVEY OF 1965

by D. R. Stoddart

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POST-HURRICANE CHANGES ON THE BRITISH HONDURAS REEFS AND CAYS: RE-SURVEY OF 1965

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INTRODUCTION

On 30-31 October 1961, Hurricane Hattie crossed the coastal coral reef area of British Honduras, shortly after an extensive survey of the geomorphology of the reefs and reef islands, carried out during 1959-1961 (Stoddart 1962, hereafter cited as ARB 87). Early in 1962 the reef area was re-surveyed, and re-photographed from the air, and many of the islands were re-mapped by ground survey. This re-survey formed the basis of a detailed report on the immediate effects of catastrophic storms on coral reefs and islands (Stoddart 1963, hereafter cited as ARB 95). With Moorhouse's observations at Low Isles, Great Barrier Reef, the work of the Pacific Science Board expedition to Jaluit Atoll, Marshall Islands (Blumenstock, editor, 1961), and the later work of Sauer (1962) and McIntire and Sauer (1965) in Mauritius, this report formed the basis for an understanding of the effects of infrequent events of considerable magnitude on the coral island ecosystem.

It is necessary, however, not only to study immediate effects of such storms, but also to evaluate their long-term implications. How long does it take a coral reef to regain its pre-hurricane state? How permanent are changes in reef and island morphology caused by exceptional storms? What is the sequence of vegetation development or recovery on storm-damaged islands? Do islands destroyed by the storm rapidly re-form? Only at Low Isles, Great Barrier Reef, do we have observations over several decades beraing on these problems (T. A. Stephenson and others 1936, Moorehouse 1936, W. Stephenson and others 1958, Fairbridge and Teichert 1948), but the storm effects there have been comparatively minor. The only study of the long-term effects of a major storm has been at Jaluit Atoll, where the effects of Typhoon Ophelia, first studied in 1958, were re-assessed three years later (Blumenstock and others 1961). Interest in these problems, and the need to add data from the Caribbean to compare with those from Jaluit, led to a further expedition to the British Honduras reefs in March and April 1965. This expedition has been only briefly reported (Stoddart 1965), and the present paper presents the main conclusions in greater detail, and documents the post-hurricane changes on the individual islands studied.

No attempt is made in this paper to draw general conclusions on the long-term significance of catastrophic storms on reefs: re-surveys of the British Honduras coast must continue until equilibrium conditions are again established before this will be possible. The British Honduras

data have been compared with those from other areas and some preliminary conclusions on the role of major storms have been drawn in a separate paper (Stoddart 1969).

Hurricane Hattie crossed the British Honduras coast from the east on the night of 30-31 October 1961. Easterly and northerly winds to the north of the storm track and south and southwest winds to the south gusted to 200 m.p.h., and a storm surge raised sea level up to 15 feet above normal levels within a zone 20-40 miles wide north and south of the storm track, especially on the barrier reef. The track and the sequence of events associated with the passage of the hurricane have been reconstructed in some detail (ARB 95, 7-20). Damage to both reefs and cays resulting from the abnormal wind and sea conditions during the storm was distinctively zoned both north and south of the storm track, as described in detail in ARB 95 and summarized in Figure 1. The present paper should be read in conjunction with this earlier work: no attempt is made here to summarize earlier data, but only to present the new data gained in 1965. The report deals first with reefs; then with changes on the cays of the barrier reef, of Turneffe, and of Lighthouse Reef, respectively; and finally summarizes the morphologic and vegetational changes on the cays between 1961 and 1965.

The 1965 investigation was made possible by generous financial assistance from Cambridge Travelling Expenses Fund, from the Royal Geographical Society, and from the Cambridge Philosophical Society. I thank these bodies for their aid, and also Mr. and Mrs. N. B. Stalker, of Belize, for their great kindness and hospitality, and Miss Evelyn L. Pruitt, Head, Geography Branch, Office of Naval Research, for transatlantic transportation. Dr. F. R. Fosberg and Dr. M.-H. Sachet again determined my plant collections, and helped in many other ways. I thank also Philip and Ronnie Young who ably took me from cay to cay in the _Sunshine_ and the _Ramrod_. Sir Peter Stallard, then Governor, and the Ministry of Natural Resources, Belize, showed much interest in this project.

RECOVERY OF CORAL REEFS

General Survey

Damage to reefs caused by Hurricane Hattie was concentrated on the barrier reef between English Cay and Rendezvous Cay, where almost all living corals were destroyed. Damage was also heavy northwards to at least St. George's Cay and south to Cay Glory, and also on the eastern side of Turneffe. Moderate damage was noted on the barrier reef from Cay Glory to Curlew Cay. In the area of heavy damage almost all trace of reef-slope groove-spur systems disappeared, leaving a bare slope; whereas in the zone of moderate damage remnants of spurs survived the storm, though flourishing coral colonies had disappeared (ARB 95, 21-29, Fig. 14).

In 1965 reefs were observed from the air along the barrier reef from St. George's Cay to Curlew Cay, a distance of 55 miles, and along the east side of Turneffe. Only a brief observation of the reefs near Half Moon Cay on Lighthouse Reef was possible.

No living coral could be seen on Gallow's Point Reef, formerly the most northerly flourishing linear reef of the barrier reef system. The sea was exceptionally clear and calm, and it was possible to see a vertical cliff-line at the foot of the gently sloping reef face, itself now devoid of corals and with no groove-spur development. At Sergeant's Cay there was some living coral on the south side of the reef patch, but little or none at Paunch, Goff's and English Cays. The numerous patches between English and Rendezvous Cays, once thickly coated with orange Acropora, were bare, with only occasional scattered patches of coral. Between Rendezvous and Cay Glory no growing coral was seen on the barrier, and no trace of groove-spur formation. Groove-spur is first seen immediately south of Cay Glory, and living coral is found on the spurs where the barrier turns southwestwards south of Cay Glory. Most of the spurs are fragmentary and living coral is absent or rare as far south as Tobacco Cay. Living coral approaching pre-hurricane luxuriance is seen on the shallower part of spurs at South Water Cay and Carrie Bow Cay, though the deeper spurs are bare. Rich coral growth is seen at Curlew Cay and southwards. In this area, south of the storm track, dominant storm waves were from the south and southeast, from the lagoon rather than the open sea; and at both Carrie Bow and Curlew Cays the southern sides of the reef patches are bare of corals.

On the east side of Turneffe, conditions in 1965 were similar to those on the barrier reef. Living corals seem almost non-existent, and although traces of reef-face lineation can be seen north of Soldier Cay there was no sign of growing corals.

These data, admittedly incomplete, suggest the following zones of reef damage and recovery:

(1) Total destruction of living corals and absence of regeneration: extending at least 15 miles north of the storm track and 12 miles south; this includes the whole of Turneffe, except for areas of local protection.

(2) Survival of traces of reef-front lineation, but death of corals and almost no regeneration: extending from 12 to 20 miles south of the hurricane track. There are no comparable data to the north of the storm track, where pre-hurricane reef growth was feeble.

(3) Reef-lineation more or less intact, but patchy survival of corals, passing into rich coral growth at a distance of 25 miles south of the storm track.

(4) Damage minor or rapidly repaired: at distances greater than 25 miles from the storm track.

This pattern of zonation is similar to that described immediately after Hurricane Hattie, and suggests that little reef recovery had taken place by 1965. Underwater observations to confirm this conclusion were made at Sergeant's Cay and Rendezvous Cay reefs.

Sergeant's Cay Reef

Sergeant's Cay stands on a small patch reef on the edge of the coastal shelf. Damage in 1961 was considerably less than on some of the patch reefs to the south, closer to the storm track, and *Montastrea annularis*, *Siderastrea siderea* and *Porites astreoides* survived the storm. *Acropora palmata* survived in places, though much broken, but *A. cervicornis* disappeared. *Agaricia* and finger *Porites* were largely destroyed (ARB 95, 22).

In 1965 the surface of the patch was covered with slabs and sticks of dead coral, covered with pink encrusting algae, with some *Halimeda*, and, on the lee side, meadows of *Padina* and *Turbinaria*. The boulders of *Siderastrea* and *Diploria* on the seaward side which survived the storm appeared healthy, though little living *Montastrea* was seen. New growth of corals is rather sparse. *Acropora palmata* forms scattered colonies up to 1 foot tall and 1-2 feet in diameter, but only a single colony of *Acropora cervicornis* was seen. There are many small colonies of *Porites astreoides* a few inches in diameter, small clumps of *Agaricia*, and larger patches of *Millepora*. Nevertheless the areas of living coral are sparse, and separated by wide areas of rubble and algae. Most of the new corals are minor reef-builders, with the exception of *A. palmata*. No larger sponges were seen, and hardly any Gorgonians, in contrast to their abundance before the storm.

Rendezvous Reef

Rendezvous Reef was studied in detail before Hurricane Hattie, and again afterwards (ARB 95, 23-25, Fig. 15), and it was possible to describe the hurricane damage in some detail using underwater observations and a sequence of low-altitude color air photographs. The air photograph cover was repeated, with underwater observation, in 1965. Immediate post-hurricane changes were summarized in 1962 as follows: "*Montastrea annularis* has survived all round the reef patch with moderate success, together with *Millepora*, which may, at least in part, have grown since the storm. More massive specimens of *A. palmata* have also survived in places. On the surface of the patch, *Siderastrea radians* can still be found in the turtle grass, but not *Cladocora* or *Manicina*. The deeper slopes round the whole patch seem to be bare. . . . As rough estimates of the amount of damage, the total reef damage may be placed at 75-80 per cent; destruction of *A. cervicornis* 100 per cent; *A. palmata* 80 per cent; and *M. annularis* 50 per cent. The extensive rubble banks along the eastern reef crest are now thickly coated with purple algae." (ARB 95, 25).

Comparison of the 1962 and 1965 air photographs shows no major changes in the areas of growing coral. *Montastrea annularis* has survived on the southwest, east and north sides of the reef, together with a few large *Acropora palmata* on the east and northeast sides. Some of the

Montastrea colonies are partly dead, some are overturned but still alive, but none seems vigorous. No Acropora cervicornis, once abundant, was seen except on the reef slope at the north point. Small new colonies of Agaricia, Millepora, and Porites astreoides were seen, together with colonies of such unimportant species as Manicina aerolata, Eusmilia fastigiata and Mycetophyllia lamarckana. Sponges and Gorgonians are fairly numerous. The carpet of dead coral rubble on the reef crest and flat is thickly coated with algae, chiefly Padina, and Thalassia is growing prolifically on the surface of the patch. The area south of the cay, and the northwest side of the reef, both stripped of corals by the storm, are still bare. The only reef-building corals found in 1965 were those which survived the storm; all new growth has been of non-frame-building forms.

Comment

The slow rate of reef recovery requires explanation, in view of the known rapidity of growth of coral colonies, especially of branching forms such as Acropora cervicornis. Following the 1950 cyclone at Low Isles, Great Barrier Reef, Stephenson and others (1958, 304) suggested that the large quantity of mobile debris produced by the storm would inhibit coral colonization and thus delay reef growth. They also suggested that a more severe storm might sweep debris off reefs completely, and that as a result recovery could then be more rapid. In addition, there may be active competition for available substrates between corals and more rapidly growing algae, particularly Padina. It is also possible that increased water turbidity may inhibit coral colonization; and, finally, there are no data on how long a species such as A. cervicornis, which suffered major damage, takes to spread from a "reservoir" such as that of the southern barrier reef to sites 50-100 miles away.

It is thus not possible to predict how long reef regeneration may take in the badly damaged areas. Stephenson and others' estimate (1958, 261) of 10-20 years in the case of Low Isles is probably too low in the British Honduras case. Applying alternative reasoning, the Rendezvous Cay reef, which was flourishing when studied in 1959-1960, must have been severely damaged by the major hurricane of 1931, suggesting a recovery period of perhaps 20-25 years. Continued observation of reef recovery is clearly needed before conclusions can be drawn.

CAYS OF THE BARRIER REEF

Ambergris Cay (ARB 95, 31-33, Fig. 16)

Ambergris Cay is the largest mangrove-sand cay on the British Honduras barrier reef, consisting of a seaward sand ridge, with coconuts and littoral woodland, and a leeward area of mangroves and drying sand flats. Hurricane damage was confined to minor shoreline retreat, near-shore sand-stripping, and the felling of nearshore coconuts. Damage was greatest at San Pedro village, where the seaward sand ridge is highest and widest, and where considerable damage was caused to buildings.

During the hurricane, beach retreat further exposed low areas of cay sandstone which had been partly visible before the storm. In 1965 this rock was still very friable, though darker in color, near San Pedro itself. Farther north it had been eroded to small residual mounds, more strongly lithified, and close to Boca Bacalar Chico these mounds formed small headlands 10 yards long between sandy bays 30-50 yards across. The zone of surface sand stripping is here about 50 yards wide along the shore, and terminates inland in an irregular cliff 1-2 feet high. Above this cliff there is a 100 per cent vegetation cover, scarcely affected by the storm. Most of the coconuts survived, though a number lack crowns. Over the stripped zone the surface vegetation cover is not more than 25 per cent, dominated by *Tournefortia* up to one foot high (compare three feet above the cliff) and *Euphorbia*, with *Ambrosia*, *Suriana*, *Sporobolus*, *Ipomoea* and *Flaveria linearis*. Other plants seen at San Pedro include *Hymenocallis*, *Cordia*, *Ipomoea tuba*, *Sophora* and *Suriana*. The littoral woodland not planted with coconuts includes *Borrichia arborescens*, *Hamelia patens*, and a *Solanum* 10-12 feet tall. Buildings have been repaired at San Pedro, and a large new jetty built on the seaward side.

Cay Caulker (ARB 95, 33-35, Fig. 17)

Post-hurricane changes at Cay Caulker have been minor. This is a mangrove-sand cay with windward sand ridge, in places fronted by *Rhizophora* and half the leeward mangrove is dead, and contrasts with the greenness of the sand-area vegetation. Trees and shrubs identified on the sand area in 1965 included *Cordia sebestena*, *Casuarina equisetifolia* (in the village), *Coccoloba uvifera*, a species of *Reynosia*, *Borrichia arborescens*, *Suriana maritima*, *Tournefortia gnaphalodes*, *Lantana involucrata*, *Turnera ulmifolia*, and a *Solanum*. There has been some recovery in stripped areas of grasses, sedges, herbs and vines, · which are densest south of the village where hurricane effects were minor. Those identified in 1965 were *Cyperus ligularis*, *Fimbristylis cymosa* subsp. *spathacea*, *Chloris petraea*, *Eragrostis dominguensis*, *Wedelia trilobata*, *Crotalaria verrucosa*, *Stachytarpheta mutabilis* v. *maxonii*, *Sida acuta*, *Ageratum maritimum*, *Ageratum littorale*, *Philoxerus vermicularis*, *Euphorbia blodgettii*, *Euphorbia mesembrianthemifolia*, *Pithecellobium* sp., *Spermacoce suaveolens*, *Ernodea littoralis*, and *Vigna luteola*. New jetties have been built on both the seaward and lagoon shores at Cay Caulker village.

Cay Chapel (ARB 95, 35-36, Fig. 17)

Cay Chapel is a largely sandy island with a narrow leeward mangrove fringe. About half the sand-area vegetation was cleared, except for some coconuts, shortly before Hurricane Hattie, in order to establish tourist facilities. The hurricane caused considerable shoreline retreat, stripping of surface sand near the seaward shore, and felling of coconuts.

On the northern, cleared, part of the island there is a zone 15-20 yards wide, along the seaward shore, of roots exposed by sand-stripping, separated by a low cliff from the main island surface. At the foot of

the stripped slope a bank of Thalassia had accumulated in 1965, followed immediately landward by a continuous zone of colonizing Tournefortia gnaphalodes 5 yards wide and 1-2 feet high. In places the Tournefortia is replaced by Suriana up to 6 feet high, Conocarpus up to 8 feet high, or low Borrichia; the cover on this lower slope is about 80 per cent. Between this shrubby zone and the eroded cliffline, the vegetation is much less dense, with large bare areas between patches of Ernodea, Cassytha, some Wedelia, and low Conocarpus. The coconut roots forming a network over the surface are rotten and can easily be pulled apart. The clifflet is lined with coconuts and dwarf Coccoloba, with an intermittent fringe of Conocarpus and some Tournefortia. The main cay surface, previously cleared, is now quite densely covered with grasses, Ernodea, and clumps of Conocarpus and Suriana. A belt of Rhizophora at the north end of the cay is dead. The creeper Merremia dissecta and the shrub Rivina humilis were collected in 1965.

Farther south, shore retreat during the hurricane revealed an exposure of cay sandstone well above high water on the seaward shore (ARB 95, 35-36). This is now separated from the sea by a belt of Tournefortia 1-2 feet high, with some Borrichia 6 feet tall, Suriana, grasses and Wedelia. The area of outcropping sandstone is scattered with seedlings of Tournefortia and Suriana. The rock is better cemented than in 1962, but still friable. The undisturbed cay vegetation inland consists of Coccoloba, coconuts, Suriana and Tournefortia, with grasses and Ageratum.

A rapid traverse was made along the west side of the cay about 100 yards from the lee shore. The vegetation cover in the former cleared area is low, with a 60 per cent cover of Ernodea, Cakile and Conocarpus. Salt efflorescence or algal binding gives a crusty surface to the silty sand.

St. George's Cay (ARB 95, 37-40, Fig. 19) Figure 3

St. George's Cay consists of an arcuate mangrove island with a sandy area at its northern end. Long cleared for use as a holiday resort, the low sandy area, only 50-100 yards wide, was cut by five deep channels when overtopped by the storm surge during Hurricane Hattie and almost all man-made structures were swept away. The northernmost point escaped extreme damage, and retained a turf of grasses, with Euphorbia, Wedelia, Hymenocallis and many coconuts. Elsewhere only patches of pre-storm ground vegetation survived, with Ageratum, Cakile, Euphorbia, Cyperus, Wedelia, and Hymenocallis, though most coconuts disappeared.

By 1965, two of the channels (B and C) had been closed by artificial fill, and the others were noticeably shallower and less sharply defined. Channel A was the deepest. The cones of submarine sand on the seaward side had altered in shape and their outlines were no longer clear, and similar deposition had taken place on the lagoon sides of D and E. Most of the mangroves are dead, except at the northern end. Ground vegetation is luxuriant except in ill-drained areas. Thus in the old cemetery, north of Channel D, there are broken Coccoloba and Conocarpus, with

Ageratum, Ipomoea, Wedelia, Stachytarpheta, Hymenocallis, Euphorbia and grasses. Farther north, outside the cemetery, the ground cover consists of Sesuvium, Ageratum, Cyperus, Batis maritima, Euphorbia and grasses. Between Channels B and C, both filled, the ground is lower and waterlogged, with Sesuvium, Batis, grasses, and even Rhizophora seedlings.

Several large houses and substantial jetties have been built since 1962, and some coconuts have been planted. Clearly it is intended to make the cay a holiday resort again, but, lacking trees, it is still an unattractive place.

Sergeant's Cay (ARB 95, 41-42, Fig. 22) Figure 4

Sergeant's Cay almost completely disappeared during Hurricane Hattie, and reformed as a smaller sandbore, which in 1962 was beginning to be colonized by plants. Four months after the storm the main colonizer on the fresh sand surface was Portulaca oleracea, in patches 1-2 feet in diameter, with small areas of Sesuvium portulacastrum and Euphorbia mesembrianthemifolia, and a single Rhizophora seedling. The 1962 island was two-fifths the area of the pre-storm cay, and lay to the west of the old island site. Aggradation and erosion of the shores was taking place, and the island was clearly not stable.

By 1965 the cay had shifted back towards its original position, though its area continued to decline, from 4500 square yards to 2600 square yards in 1962 and 2200 square yards in 1965. The vegetation had developed considerably. On a small central area, where part of the pre-storm surface can still be seen (560 square yards, or 25 per cent of the 1965 area), there is a continuous herb mat of Ipomoea (I. tuba and I. pes-caprae), Wedelia trilobata, and Euphorbia (E. mesembrianthemifolia, E. blodgettii). Both Portulaca and Sesuvium are absent. Shrubs, absent in 1962, are represented by three Conocarpus up to 10 feet tall, six Suriana maritima up to 5 feet tall, and three Tournefortia gnaphalodes less than 3 feet tall. There is a single seedling of Coccoloba uvifera 2 feet high. Both Euphorbia and Ipomoea are beginning to colonize the bare sand surrounding the vegetated area, and at the eastern end there is a conspicuous white-flowered clump of Eustoma exaltata. Other herbs collected included Cakile lanceolata, Batis maritima and Philoxerus vermicularis. In three years, therefore, the number of species on the cay increased from 4 to 13. The island is still mobile, however, and further changes can be expected.

Goff's Cay(ARB 95, 43-44, Fig. 23) Figure 5

Before the hurricane, Goff's Cay was a small coconut-covered sandy island, with a thin ground vegetation of herbs, vines and grasses. During the storm it was severely eroded, and the vegetated area reduced from 2100 to 950 square yards. By 1962 much fresh sand had accumulated around this remnant to give a total area of 2650 square yards. In 1965 slight recession of the southern shore had been balanced by considerable aggradation of new beach ridges on the north side, giving a total area of 3250 square yards, very slightly less than the pre-storm area. The

rubbly shores of 1962 are now covered with sand, and the beachrock seen in 1962 has been covered with rubble and cobbles.

The immediate post-hurricane vegetation consisted of dead coconuts, a broken Coccoloba, and patches of Portulaca oleracea, the only colonizer. By 1965 the core-area was covered with a mat of Euphorbia, Sesuvium, Ipomoea, and Ernodea littoralis. Ipomoea vines are spreading out on to the fresh sand. Eighteen coconuts planted since the storm have grown up to 3 feet tall. The number of plant species had thus increased from 1 in 1962 to 5 in 1965.

As in 1962 there is an unvegetated sandbore north of the cay, apparently migrating in position with weather changes.

English Cay (ARB 95, 44-45, Fig. 24)   Figure 6

Before Hurricane Hattie, English Cay was a settled, coconut-covered island with little ground vegetation and a resident population of pilots and lighthouse keepers. In the storm the area of the cay decreased from 5750 to 3150 square yards by shore retreat on all sides. Eight out of 98 coconuts remained, together with a single broken Coccoloba and an ancient Rhizophora. By 1965 there had been little change in the morphology of the island, except for the leeward sandspit. Eighteen coconuts had been planted, and there is a patchy ground cover of Sesuvium, Euphorbia, and Portulaca oleracea. The old Rhizophora and the Coccoloba are dead; but a surviving pawpaw tree (Carica papaya) was found. With the reoccupation of the cay by people it is clear that natural regeneration of the vegetation is not taking place.

Rendezvous Cay (ARB 95, 47-49, Fig. 28)   Figure 7

Like English Cay, Rendezvous before the storm was inhabited, covered with coconuts, and subject to periodic clearing of ground vegetation. Its gross morphology was largely man-induced, with a large dry-land area of dumped conch shells. The area of the cay changed little during the storm, though much surface sand was stripped and deposited along the west shore, partly burying the conch accumulations. All the coconuts disappeared, but the original root-bound surface remained partly intact. Within five months many pioneers had colonized this surface. Portulaca oleracea was most widespread, with the sedge Cyperus planifolius and grasses such as Sporobolus. Other constituents of the ground vegetation in 1962 were Sesuvium portulacastrum, Euphorbia mesembrianthemifolia, Ipomoea pes-caprae, Cakile lanceolata, Fimbristylis cymosa and Philoxerus vermicularis. Solanum lycopersicum was collected, and seedlings of Rhizophora and Tournefortia were seen. Forty young coconuts were planted at this time.

By 1965 the vegetation had changed considerably in pattern and in density. Most of the ground surface was covered with a mat of Ipomoea and Euphorbia, with smaller areas of Wedelia trilobata and Sesuvium. Cyperus, Ageratum, Cakile and Sporobolus were present in patches, but Portulaca was rare. The coconuts had grown up to 10 feet tall, with the bigger trees in the center of the island. At the northern end of the cay there were low bushes of Tournefortia and Suriana, with a lone

Casuarina rapidly being undermined by the sea. One of the broken Coccoloba still lived, together with Rhizophora seedlings. The number of species in 1962 was 12, and in 1965 not less than 16.

Active erosion was continuing in 1965, when the whole of the eastern shore had retreated 10-15 yards from its 1962 position. Many of the newly-established shrubs and coconuts are being undermined by this retreat, which is considerably reducing the width of the northern end of the island. There is a small hut on the island, intermittently occupied.

Tobacco Cay (ARB 95, 53-55, Fig. 31)

Tobacco Cay is a triangular island 300 yards long and up to 150 yards wide in the south, covered with coconuts and permanently inhabited. It was mapped in 1960 and again in 1961, when the main changes were in the size of seasonal sand ridges along the south shore and in the pattern of ground vegetation. In 1960 this was dominated by dense Stachytarpheta up to 3 feet tall, Wedelia trilobata, Hymenocallis, and Ipomoea (I. pes-caprae, I. stolonifera). Smaller and apparently more recently cleared areas had a thin cover of Euphorbia, Canavalia and Vigna luteola. Sesuvium was found around the shores. Changes between 1960 and 1961 showed that the pattern of vegetation was largely a function of repeated clearing by the inhabitants.

Hurricane winds in 1961, from the southwest, blew down many coconuts, and deposited thin carpets of fresh sand up to 15 yards wide along the south and west shores. The east shore retreated up to 14 yards. After the hurricane the surface was covered with fallen coconut trunks, especially in the south. Terminalia survived, even along the south shore. Wedelia was much less widespread in early 1962, when the dominant ground cover consisted of Ipomoea and Stachytarpheta, with some Sesuvium, Vigna luteola, Portulaca oleracea, Euphorbia and grasses.

By 1965 many of the fallen coconuts had been cleared, and other living trees seen included Coccoloba, Cordia, Terminalia, a small Carica, and Bumelia retusa. Wedelia had expanded greatly in the center of the island, except where very recently cleared; and the rest of the surface was covered with Stachytarpheta, Ipomoea, Hymenocallis and Euphorbia. The changes in distribution of these plants since 1962 were very noticeable. Ipomoea and Sesuvium are the chief beach-crest colonizers, together with small areas of Tournefortia gnaphalodes (not previously seen). The southern sandspit, slightly reduced in size, is being colonized by Sporobolus, Euphorbia, Sesuvium, Ipomoea, several Tournefortia seedlings, and a single Sophora tomentosa 2-1/2 feet tall. Other plants seen on Tobacco Cay included Canavalia, Portulaca, Cyperus, Rhizophora, Avicennia and Conocarpus.

Apart from the thinned coconut canopy and the number of broken trunks, the effects of the hurricane are no longer obvious. The fresh sand carpet had already been colonized by Ipomoea in 1962, and even where surface sand was stripped in 1961 there has been colonization by Ipomoea, Euphorbia and other plants.

South Water Cay (ARB 95, 55-57, Fig. 32)

Post-hurricane changes at South Water Cay have been small. The leeward beaches have accreted slightly, and the eastern shore has retreated. There has been slight erosion also at the south point. The northern part of the island, with a thicket of coconuts, suffered little change in 1961 apart from shore retreat. Coconuts, Thrinax and Coccoloba were thriving here in 1965, with Wedelia, Ipomoea, Batis maritima, Euphorbia, and Sesuvium. In the center of the cay, where large houses and paths flanked with Hibiscus were formerly maintained, the surface is now covered with Euphorbia, Ipomoea, Stachytarpheta, Ambrosia and Cassytha, with a few Coccoloba trees and some Hymenocallis. Along the eroding eastern shore there is some bushy Borrichia with much Cassytha, a few Tournefortia seedlings, and a ground cover of Sesuvium, Ipomoea, Euphorbia and Sporobolus. On the southern part of the island, many young coconuts were planted after the hurricane, and in 1965 some were 10-15 feet tall. Two small Casuarina survived on the lagoon shore. One or two Rhizophora are alive on the east shore but there are very few seedlings. Effects of the hurricane are no longer obvious. Though many houses were damaged in 1961, new ones have been built, including two at the north point, and a substantial building has been erected near the south end by a Belize nunnery. A new jetty has been built for this in the west bay.

Carrie Bow Cay (ARB 95, 57-58, Fig. 33)

This island, used as a private holiday resort, was covered with coconuts in 1960. Morphologic changes were slight during the storm, many coconuts still stood, and Euphorbia formed a patchy surface cover in 1962. By 1965 a number of small coconuts had been planted to replace those destroyed, and low Tournefortia bushes were growing along the northern half of the seaward shore. Ground cover included Euphorbia. Ipomoea, Sesuvium and grasses, but is clearly often modified by man.

Bugle Cay (ARB 95, 67-68, Fig. 43)

Bugle Cay is a mangrove island with a small low sandy area at its west end, cleared and planted with coconuts. This sandy area suffered considerable marginal erosion and surface sand stripping during the hurricane; many coconuts stood, but the adjacent mangrove was much broken and defoliated. Coconuts planted since the storm were 2-3 feet tall in 1965. The area between the sand ridge and the mangrove, cleared by man before the storm, is now being colonized by Sesuvium and Batis maritima. There is a small patch of Sesuvium at the northern end of the sand ridge, with Batis, Euphorbia and Cyperus, but the rest of the surface is kept artificially cleared. A substantial hurricane-proof concrete house has been built for the lighthouse keeper since the storm.

Scipio Cay (ARB 95, 66-67, Fig. 42) Figure 9

Scipio Cay is a low-lying, sandy island, covered with coconuts, with a large central Avicennia swamp. Beach ridges on the east and southeast sides are covered with Thrinax. The hurricane caused

considerable beach erosion and cliffing along the east shore, followed by the deposition of a ridge of fresh shingle up to 20 yards wide and 2 feet thick on the scoured surface, with a ridge of shingle and rubble 10 yards wide and generally less than 3 feet high forming a new shoreline. This outermost ridge in 1962 was discontinuous and also enclosed a large pool at the south point; it was unvegetated. By 1965 this fresh shingle ridge had been pushed landward and undergone minor changes in outline. Near the east point 50 yards of the outer ridge have disappeared, but farther south gaps have been infilled. The main colonizer of the bare shingle is Sesuvium, followed by Sporobolus and Euphorbia. Shrubs are represented by a single Sophora seedling. It seems likely that the ridges will continue to migrate towards the old cay shore, and thus ultimately replace the zone eroded in 1961. The wedge of perched shingle on the old cay surface is now being colonized by neighboring vegetation.

Colson Cay (ARB 95, 67, Fig. 42)   Figure 10

Colson Cay is very similar to Scipio, being formed of a peripheral coconut-covered sandy area and central Avicennia marsh. Much of the southeastern shore is covered by Thrinax. As at Scipio, beach retreat and cliffing in 1961 were followed by deposition of a shingle wedge, especially on the east side, and formation of a shingle ridge offshore. The ridge itself was 2 - 2-1/2 feet high, and separated from the undercut shore by a low carpet of shingle 15-20 yards wide, by closed pools, or by open water. Part of the ridge, on the southeast shore, was eroding in 1962. Considerable changes had taken place by 1965 in the ridge morphology. The long spit at the east point had been welded to the shore, enclosing a pool 6-12 inches deep filled with algae. Southwards from the east point, where erosion was noted in 1962, the shingle shoreline has retreated 5-10 yards, and is now cliffed and still retreating. North of the east point, however, a new low ridge of fresh white shingle has been built against the grey hurricane ridge of 1961, so that there has been a general advance of the shore of about 5 yards. Sesuvium is again the main colonizer of the shingle, with some patches of Euphorbia, Sporobolus and Cassytha, and two small Tournefortia bushes. Little change was noted in the main cay vegetation; though broken Cordia sebestena trees were in flower.

CAYS OF TURNEFFE

Pelican Cay (ARB 95, 72-73, Fig. 44)   Figure 11

Pelican Cay is a sandy island with a thicket of Cordia sebestena, Bursera simaruba and Thrinax, and a belt of Rhizophora to leeward. The vegetation was badly damaged during the hurricane, when much of the surface sand on the seward side of the cay was eroded (leaving remnants of cemented shingle standing above the new beach level), and fresh rubble and shingle was deposited along the margin of the vegetation thicket. The Rhizophora was completely defoliated during the storm. No morphologic changes were noted in 1965. The most striking change was the colonization of the shingle-carpet areas by Tournefortia

gnaphalodes, and to a lesser extent by Sesuvium. Much of the broken Cordia was in flower, some of it being found in the Bursera area. Ipomoea tuba was conspicuous, climbing on the broken trees and extending out over the shingle carpet. A single seedling of Sophora was seen. The osprey nest seen in 1962 still existed, and a newly hatched green turtle was seen close to the shore in 1965.

Cockroach Cay (ARB 87, 46, Fig. 25; ARB 95, 73-74, Fig. 45)

Cockroach Cay is a sandy island, densely covered with coconuts before the 1961 hurricane. During the storm all the coconuts were removed by overtopping waves, which eroded much of the surface sand. In early 1962, the surface on the seaward side was formed of bare coconut roots, and that to leeward of coarse rubble and roots. One or two Cordia survived, much broken, together with patches of the original turf cover; but immediately after the storm the only vegetation consisted of sparse Euphorbia, Cyperus and Sesuvium, and one or two Rhizophora seedlings. The seaward shore was cliffed, exposing a soft incipient sandstone at the northwest end. In 1965 morphologic changes had been minor, though the degree of cementation of the outcropping rock had increased to form a hard rock ledge 4-6 inches above low water. The densest vegetation is at the north end of the cay, with a continuous cover of Ipomoea, Canavalia and Sesuvium. Along the seaward shore there is a fringe of Tournefortia, Sophora and Suriana bushes, with Sesuvium and Ipomoea, but most of the cay surface still has but a sparse cover of Cyperus, Euphorbia, Ageratum and Canavalia. Broken Cordia stumps are in flower, especially along the lagoon shore.

On the adjacent Cay V of the Cockroach Group, the pre-hurricane vegetation of bushes was largely killed and partly blanketed by storm shingle in 1961; leeward mangrove was defoliated. In 1965 the fresh shingle was colonized only by a small patch of Sesuvium. In the vegetation thicket Tournefortia was most luxuriant, forming patches up to 4 feet high and 10 yards in diameter. Suriana, Conocarpus and Coccoloba are also present, with a ground cover of Euphorbia and Cyperus. About half of the leeward Rhizophora is alive.

Soldier Cay (ARB 87, 43-44, Fig. 21-23; ARB 95, 74-76, Fig. 46)

The coconut-covered sandy island of Soldier Cay was stripped of all vegetation by Hurricane Hattie and transformed into an eroded surface, with exposed coconut roots, flanked by a wide shingle carpet on the lee side and a narrow ridge on the seaward side. Four coconuts only survived the storm, and in 1962 there was a sparse and patchy growth of Sporobolus, Cyperus, Ageratum and Portulaca. In 1965 vegetation on the old cay surface was still sparse. Much was still bare, with patches of Ipomoea, a grass (probably Sporobolus), Cyperus and Ageratum. Along the seaward margin of the old cay, overlooking the hurricane shingle, there is a shrub zone dominated by Tournefortia, together with Suriana less than 3 feet high, and a ground mat of Sesuvium spreading out onto the shingle. Vegetation is more extensive on the leeward shingle area, with a 50 per cent cover of Sesuvium, Euphorbia, Cyperus, Ipomoea and Wedelia, two clumps of Tournefortia and two of

Suriana, and a single Sophora in flower, 3 feet tall. There is also a small patch of very fleshy Sesuvium on the shingle bar or islet east of the cay. Conocarpus, Avicennia and Coccoloba survived on the main island from before the storm. Morphologic changes since 1962 have been limited to slight shoreline retreat around the leeward shingle area and some changes in the shape of detached shingle islets.

Little Calabash Cay (ARB 87, 44, Fig. 19; ARB 95, 76-77, Fig. 47)
Figure 12

Little Calabash Cay was formerly the center of the Turneffe copra industry, with houses, a jetty, and coconut palms. All human installations were destroyed during the hurricane, and so were all the coconuts. Considerable surface and marginal erosion reduced the size of the island, and in 1962 the surface was low-lying, with exposed roots and two brackish pools. A large fresh sandspit built up at the northeast end of the cay following the storm. In 1962 the only vegetation was a scatter of Ageratum, Wedelia, Cakile and grasses over the old land area. By 1965 minor shoreline adjustments had taken place, with some sediment accretion at the southern end. The pools had disappeared, and the surface was covered with patches of grasses and herbs. Two areas of Sesuvium, an area of grass, and a large area of Batis maritima on the site of the largest pool were distinctive. In addition there is a mixed area of Ageratum, Euphorbia and Wedelia. Shrubs are represented by two bushes of Borrichia arborescens, seedlings of Tournefortia and Suriana, and low Conocarpus. The number of species present has thus increased from not less than 4 to not less than 10 in three years. A small hut has been built on the island, and natural regeneration of the vegetation will thus not take place.

Big Calabash Cay (ARB 87, 42, Fig. 20; ARB 95, 77-78, Fig. 48)

Before the hurricane the vegetation of Big Calabash resembled that of Little Calabash, being dominated by coconuts with a ground cover of grasses and herbs, but the island was much larger and hurricane damage was therefore less intense. Though the shoreline retreated and there was some scouring and channel-cutting by overtopping water, much of the original turfed surface survived, though almost all the coconuts, and the Rhizophora seedlings between it and the adjacent small island, were swept away. In 1965 there was a 90 per cent ground cover of coarse grasses, all sterile, together with Ageratum, Batis maritima and Euphorbia. The southern end of the island has a fringe of shoreline Borrichia, some Conocarpus, and a mat of Sporobolus, and elsewhere there are some Borrichia and young newly-planted coconuts. On the seaward shore a new Rhizophora has grown to a height of 3 feet. A small house has been built on the cay by a resident fisherman.

On the adjacent island (East Cay I) there is a ground cover of Sesuvium and Euphorbia and a number of Borrichia bushes. The pre-hurricane Rhizophora is all dead. East Cay II now consists only of dead shrubs and rubble.

Deadman I (ARB 87, 37-38, Fig. 16; ARB 95, 79-80, Fig. 49)

The post-hurricane surface of Deadman I consisted of bare roots and fresh shingle, and an incipient "promenade" of cay sandstone was exposed by beach retreat on the south and east shores. A few spider-lilies (Hymenocallis) survived at the eastern end, with some Borrichia bushes, a patch of Sesuvium, and sparse Euphorbia, Ageratum and Cyperus. By 1965 the incipent promenade at the east end had disappeared through erosion, but that along the south shore was more strongly lithified. The northern ridge of hurricane shingle had been eroded slightly, but otherwise there were no morphologic changes. In the area of stripped roots, ground vegetation cover was still patchy: species present included Ageratum, Euphorbia, Sesuvium, Ernodea, Wedelia, Cyperus, and Echites umbellata. Much of the shingle was bare, except for a few small Borrichia and Tournefortia bushes and some Hymenocallis. Two coconuts are still alive, and two Thrinax; the old Avicennia at the east end still has some leaves. A single seedling of Sophora was noted.

Deadman II (ARB 87, 38, Fig. 16; ARB 95, 80, Fig. 50)

At Deadman II the hurricane killed most of the vegetation thicket and deposited a carpet of shingle over the seaward side of the cay. Beach retreat also exposed an incipient promenade. Borrichia, Hymenocallis, Ageratum, Sesuvium and Sporobolus were noted in 1962. In 1965 much of the incipient promenade had gone, particularly in the south, though the rock which remained was more strongly lithified. On the fresh shingle area there are patches of Tournefortia, Conocarpus, Borrichia, Hymenocallis, Euphorbia and Sesuvium. In the thicket area there is a 100 per cent ground cover of Ageratum and Euphorbia, with Conocarpus along the west shore, and some Thrinax 3-4 feet tall. Of four coconuts which survived the storm, one was fruiting.

Deadman IV (ARB 87, 39, Fig. 17; ARB 95, 81, Fig. 51)

Deadman IV closely resembles Deadman II in both pre- and post-hurricane characteristics. The fresh shingle had in 1965 been colonized by a belt of Tournefortia, with a single Suriana, and a ground cover of Sporobolus, Euphorbia and Ipomoea. New Thrinax had reached heights of 2-4 feet. In the thicket area there is a cover of grasses, Euphorbia and Ageratum, with some Borrichia, and small Rhizophora along the west shore. Four of nine coconuts which survived the storm were fruiting.

Deadman V (ARB 87, 39-40, Fig. 18; ARB 95, 81, Fig. 52)

After the hurricane, Deadman V consisted of a western sector of defoliated mangrove, and an eastern sector of sand formerly covered with coconuts, and in 1962 partly covered with Euphorbia and Sporobolus and partly bare. By 1965 the Euphorbia and Sporobolus had colonized much of the bare area, and several patches of Sesuvium had appeared. There are single bushes of Borrichia and Suriana. Four coconuts were still alive. Most of the mangrove is dead, but seedlings of Rhizophora are numerous in shoal water south of the cay.

CAYS OF LIGHTHOUSE REEF

Sandbore Cay (ARB 87, 56-58, Fig. 28; ARB 95, 89-91, Fig. 56) Figure 13

Sandbore Cay at the north end of Lighthouse Reef is an island of complex geometry much altered by Hurricane Hattie. Before the hurricane it consisted of three spits of unequal size extending leeward from a sandy seaward beach, which had itself been retreating westwards (lagoonward) for some decades. The island had a dense vegetation of coconuts, shrubs, herbs and grasses. During the hurricane the two northern spits were cut off from the rest of the cay by a channel 65 yards wide, and the southern spit was cut into two parts by a channel 50 yards wide. The first channel had filled with fresh sediment by early 1962, but the other remained open, the former shorelines being marked by lines of beachrock. The scoured cay surface retained only a few patches of grasses and Euphorbia at the eastern end; but on the larger northern spit coconuts, Coccoloba and Conocarpus still stood. Most of the shoreline Tournefortia and Suriana had been swept away, but the ground surface inland was patchily covered with Sporobolus, Cakile, Euphorbia and Ambrosia. Ipomoea appeared to have declined in abundance, Cenchrus to have increased. Tournefortia seedlings were noted along the northwest shore in May 1962.

Considerable changes had taken place in morphology and vegetation by 1965. The leeward sandspits had altered position; the northeast shore had continued to retreat, exposing fresh beachrock; but the main change was the growth of a sandbar across the narrow entrance to the bay between the northern and southern spits. This bar is 1 foot high and 35 yards wide, still unvegetated in its central part. The body of water thus enclosed is orange-brown in color and stagnant, with foul-smelling margins. The main part of Sandbore is thus effectively a single island with an interior pool. The gap between this main island and the relic of the southern spit is still 2-3 feet deep and kept open by vigorous water movement; the beachrock in the gap is densely covered with Diadema.

On the main island it is convenient to discuss vegetation changes in terms of (a) the southern spit and eastern end, and (b) the large northern spit. In 1962 the southern spit and east end of Sandbore had a surface of bare roots, thinly covered with rubble, and with little vegetation except for grasses and Euphorbia. It is now covered with a dense growth of Ipomoea, Euphorbia and grasses, with at the east end areas of Ambrosia and Sesuvium. There are several Tournefortia bushes up to 3 feet tall, and Sophora tomentosa 18 inches tall. The neck of sand filling the northern channel has been colonized by grasses, Ipomoea, Suriana and Cassytha, with some small Tournefortia. The density of vegetation on the northern spit varies considerably. Patches of Coccoloba and Conocarpus which survived the storm on the margins of the interior pool are now thriving. Over the rest of the area, vegetation is still sparse where sand was stripped and coconut roots were exposed, but is more luxuriant where original pre-hurricane vegetation maintained a ground cover and soil was not lost. Superficial scour channels are

still visible in the stripped areas. Most of the northern spit is covered with an assemblage of Ambrosia hispida, Ernodea littoralis, Ageratum maritimum, Euphorbia sp., and grasses (including Sporobolus). There are several Borrichia bushes, and, along the northwest shore, patches of Tournefortia up to 6 feet in diameter and 18 inches tall. The sandspit at the west end is being colonized by Ipomoea, Euphorbia, Cenchrus tribuloides, Sporobolus and Tournefortia. The remnant of the southern spit has a dense vegetation of Borrichia, Suriana, Tournefortia and Sophora, with a ground layer of Ipomoea, Wedelia, Canavalia, Ambrosia and Ernodea.

A new lighthouse has been built on the north spit to replace that destroyed in Hurricane Hattie, together with a jetty on the lee side. The light is automatic, and there is no provision for a resident keeper. The remains of the "hurricane-proof" house destroyed in 1961 still stand near the east point.

Northern Cay (ARB 87, 58-62, Fig. 29; ARB 95, 92-94, Fig. 57) Figure 14

Post-hurricane changes at Northern Cay are only considerable at the northeast point. This was cut back 120 yards by the storm, but by 1965 had built out again at least 80 yards. The surface of this new spit, together with the bare area formed by the storm, is a source of blowing sand which has accumulated at the edge of the vegetation cover, around bushes and grass tussocks, to form dunes several feet high. The bare nearshore areas are being colonized by Suriana, Tournefortia and Borrichia, with Sporobolus and Euphorbia. Along the east coast, much battered Coccoloba is still alive, and Pithecellobium is distinctive. Inland, there has been no interference with vegetation since the storm, as the cay is no longer inhabited, and there is a dense growth of shrubby vegetation, with Conocarpus up to 10 feet tall, Thrinax, Coccoloba, and some new coconuts. Ernodea littoralis is prolific on the ground.

Half Moon Cay (ARB 87, 64-77, Figs. 30-34; ARB 95, 94-98, Figs. 58-59)

At Half Moon Cay the three main vegetation types are (a) Cordia-Bursera woodland, (b) coconuts with ground vegetation, and (c) coconuts with no ground vegetation. During the hurricane the Cordia-Bursera woodland along the southeast side of the cay was much damaged, especially near the shore. To the north of this, in the area of uncleared ground vegetation, many coconuts were felled by the storm. On the eastern part of the cay, with no ground vegetation, few coconuts were felled, but a Tournefortia hedge disappeared at the east point.

Since the hurricane, fallen trunks have been cleared from the east end of the cay and young coconuts planted there and at the south point. Shrubs have colonized much of the shore at the east point and on the western half of the cay. At the eastern end there are several Tournefortia less than 1 foot high, with a littoral fringe of Wedelia, Euphorbia, Sesuvium and grasses. Tournefortia, with Sporobolus and Euphorbia, is found patchily along the southeast shore and forms a tall hedge at the south point. Along the north shore Sesuvium forms a carpet 1-2 yards wide, with some Euphorbia and grasses; immediately inland

there is a stripped zone with sparser vegetation, and then the old cay surface, with a dense growth of Hymenocallis, Wedelia, Stachytarpheta, Euphorbia, Cyperus and grasses. Near the shore there are a few Tournefortia bushes up to 3 feet tall. Sesuvium and Canavalia, with Tournefortia bushes, blanket the low ground at the east end of the island.

Along the south shore, where retreat of the Cordia-Bursera thicket was greatest, changes have been considerable. Bursera broken by the storm is generally dead, but Cordia has usually survived, even when physically badly damaged, and the frigates and boobies were nesting normally in this woodland in April 1965. The outer margin of the woodland is irregular, and after the hurricane there was a zone of fresh sand, shingle and rubble 20-30 yards wide along the whole shore. Curiously this zone in 1965 was almost bare of grasses and other ground-layer plants, except for a little Cyperus and Sporobolus and occasional Iresine diffusa with horizontal roots up to 5 feet long, but there is an approximately 50 per cent cover of Tournefortia gnaphalodes, in patches 2-3 feet high and 10 yards in diameter. This is the most luxuriant growth of pioneer Tournefortia seen on these reefs.

The damaged lighthouse was repaired in 1963, and a new hurricane-proof house erected nearby.

Long Cay (ARB 87, 77-81, Fig. 35; ARB 95, 98-99)

No morphologic changes were noted at Long Cay in 1965. On the eastern ridge no new coconuts had been planted, though there had been some natural regeneration. There is a patchy cover of Euphorbia, Wedelia, sedges, and grasses (Sporobolus virginicus, Eragrostis dominguensis), with much Ernodea littoralis. Conyza canadensis v. pusilla was collected here for the first time. Tournefortia is found occasionally along the shore, with some Suriana. There is surprisingly little Borrichia, and only occasional Sophora tomentosa. Lantana involucrata was also collected. In the northern sandy area, vegetation is dense and tangled with many fallen trunks. Wedelia, Stachytarpheta, Suriana and Ernodea are conspicuous; and other plants seen include Sophora, Borrichia, Tournefortia, Euphorbia, Cassytha, Ageratum, Ambrosia and Cordia. The island is again permanently occupied, and in 1965 a light airplane strip was being cleared with power-saws near the southern margin of the northern sand area.

GEOMORPHIC CHANGES ON THE CAYS

Following the 1962 survey, four zones of hurricane damage on cays were distinguished (Figure 1): (1) a zone of maximum damage 15-20 miles north and south of the storm track, with most intense winds and maximum storm surge, in which small cays disappeared, others were stripped of vegetation and underwent surface sand-stripping, beach-retreat and channel-cutting, and mangroves were completely defoliated; (2) a second zone 15 miles wide, north and south of zone 1, subject to considerable wave and wind action but without a pronounced storm surge, in which the main physiographic changes were limited to beach retreat and nearshore

erosion and deposition, and in which vegetation changes were small apart from defoliation of mangroves in more exposed locations and felling of coconuts by wind; (3) a zone in the barrier reef lagoon 30-40 miles south of the storm track, where vegetation changes and erosional effects were small, but where bars of sand and shingle were deposited on the south and east sides of cays; (4) the zone of no damage, which on the south side lies not less than 40 miles from the storm track. Changes in the period 1962-1965 are best summarized in terms of morphologic types identified in 1962, which roughly correspond to these zones, arranged from the zone of maximum to that of least damage.

Types of adjustment

1. None of the sand cays which disappeared during Hurricane Hattie (St. George's East, Paunch, Glory, Bokel, Saddle) had reappeared in 1965.

2. The vegetated sand cays reduced to sandbores (Sergeant's, Goff's) continue to change in form and location, partly stabilized by the remains of pre-storm root-bound surfaces. The new islands are generally slightly smaller than those before the storm.

3. Vegetated sand cays in Zone I stripped of vegetation and subject to marginal and superficial erosion (Big and Little Calabash, Sandbore, Cockroach, English, Rendezvous) generally show only minor geomorphic changes, though in most cases the retreat of windward shores is continuing, particularly at Rendezvous. Features above high water are unchanged, though channels cut through former land surfaces have in some cases shoaled or filled (St. George's, Sandbore).

4. Vegetated sand cays in Zones I and II with major vegetational but minor geomorphic damage in 1961 (Half Moon, Tobacco, South Water) have undergone only slight shoreline readjustments, either of beach retreat or of spit aggradation. At Northern Cay small dunes have been formed by the Trades blowing over a recently developed and unvegetated sandspit.

5. Cays of Zone III with peripheral shingle deposits have undergone adjustments in form of the hurricane-deposited shingle bars and spits, which have migrated landward (Scipio, Colson). No morphologic changes have taken place on the stripped marginal surfaces of the cays themselves.

6. On the larger mangrove-sand cays of Zones I and II (Caulker, Chapel, Big Cay Bokel, Northern Cay), where damage was limited in 1961 by the size of the island, the changes resulting from the hurricane, such as nearshore surface scouring and channel-cutting, above high water, have remained unaltered. Shoreline changes are less marked than on simple sand cays.

Comment

It is clear from the 1965 survey that post-hurricane changes have been negligible above high water mark on the cays: on stripped surfaces, often scattered with hurricane rubble, no subsequent accumulation of

sand has taken place, and no marked soil formation on newly exposed surfaces, while accumulations of hurricane-deposited sand and shingle beyond the limit of wave action remain unaltered. On cay margins changes have been more marked, though generally minor. The evidence of continued retreat of windward beaches, reaching a maximum rate of 9-15 feet/year at Rendezvous Cay, and of the failure of cays destroyed to reappear, suggests that the destruction of reef corals in Zones I and II effectively allows larger waves access to reef flats and beaches. Increased erosion may thus continue until the reefs recover, and in the case of narrow islands such as Rendezvous this could lead to the delayed disappearance of cays as a secondary result of the hurricane. Shingle bars on reef flats, while not widespread, have been pushed landward, and in some cases combed out to form shingle flats; similar adjustments of reef flat shingle bars have been noted in post-hurricane surveys at Jaluit Atoll (Blumenstock and others 1961).

Exposures of partly lithified rocks revealed by Hurricane Hattie in most cases survived in 1965. These include beachrock, promenades of cay sandstone, fragments of a probably phosphatic conglomerate well above sea level on Half Moon Cay and Pelican Cay, and a high-standing cay sandstone on Cay Chapel. In all cases the degree of lithification is greater than in 1962, especially on the surface, suggesting that the incipient bonding below the ground which leads to the survival of the bonded material to form topographic features has been followed by a secondary subaerial or in some cases intertidal cementation process. The ledges of cay sandstone at Big Cay Bokel are of special interest, for the friable root-filled soft sandstone of 1962 is now a compact rock similar to that long exposed elsewhere on the Turneffe eastern sand ridge; the coconut roots penetrating the rock in 1962 have now rotted and are disappearing. These exposures clearly demonstrate that lithification is a contemporary process capable of forming rock ledges above present sea-level without any necessity for sea-level change.

VEGETATION CHANGES ON THE CAYS

The minor nature of geomorphic changes on the cays and of reef growth is in contrast with the considerable and rapid vegetation changes which have taken place in the 3-1/2 years since Hurricane Hattie. These vegetation changes have not, however, been uniform in nature or rate, and may be conveniently discussed in terms of the colonization of different substrates prepared by the hurricane, and the recovery of different vegetation types following the storm.

Colonization

1. Primary colonization of bare islands.

The four cays of Sergeant's, Goff's, English and Rendezvous on the northern barrier reef lost all vegetation apart from broken tree stumps during Hurricane Hattie. By early 1962 *Portulaca oleracea* was the chief colonizer of their bare surfaces, in places still partly bound by roots, and *Euphorbia mesembrianthemifolia* and *Sesuvium portulacastrum*

were also present. The three most damaged cays had 4, 1 and 2 species of plants growing on them five months after the storm; 3-1/2 years afterwards the numbers had increased to 13, 5 and 5, respectively. At Rendezvous, where more of the original bound surface survived, the number of species increased from 13 to 16 in the same period. Of these colonizing species, three were common to at least three of the four islands in 1965: Sesuvium, Euphorbia and Ipomoea; Cocos was found on three islands but had been artificially planted. The formerly dominant Portulaca was found on two islands but was not conspicuous. Other species found on two out of four islands were Wedelia, Cakile, seedlings of Tournefortia and Suriana, and relict Coccoloba. At least 11 other species occurred on only one of the islands: this diverse group includes Ageratum, Euphorbia blodgettii, Ernodea littoralis, Batis maritima, Philoxerus vermicularis, Cyperus sp., Sporobolus sp., Eustoma exaltata, Conocarpus erecta, and Casuarina equisetifolia. On the more badly damaged islands the pioneers of 1962 were often absent in 1965: thus at Sergeant's Cay three species out of four in 1962 were absent in 1965 (Portulaca oleracea, Sesuvium portulacastrum, Rhizophora mangle); and at Goff's Cay the single species present in 1962 (Portulaca oleracea) was not seen in 1965. The greater stability of surface on Rendezvous Cay, which was stripped of vegetation and heavily eroded without being destroyed, is reflected both in the larger number of species present in 1962 and in the small changes and low rate of extinction between 1962 and 1965.

2. Colonization of sandy shores and sand ridges.

Fresh sand ridges were lodged on the windward shores of several cays during Hurricane Hattie, particularly on Tobacco and South Water Cays, and fresh sand beaches were prepared for plant colonization at Sandbore and Half Moon Cays. At Tobacco Cay the new sand ridge had been colonized within five months by an almost complete cover of Ipomoea. In 1965 Tournefortia, Sporobolus and Euphorbia were found in all four cases mentioned; Ipomoea and Sesuvium in three. The bushes of Tournefortia varied up to 3 feet in height and 6 feet in diameter. Other plants less typical of this habitat but found in at least one of the cases were Sophora tomentosa, Borrichia arborescens, Wedelia trilobata, Cassytha filiformis and Cenchrus tribuloides.

3. Colonization of shingle bars.

Shingle bars built by the hurricane are rare except on the cays of the central barrier reef lagoon, such as Scipio and Colson; small bars are found close to some larger islands, such as that near Soldier Cay. In 1965 the main colonizer in each of these three cases was Sesuvium portulacastrum, with smaller patches of Sporobolus and Euphorbia in two cases. Seedlings of Sophora and Tournefortia were each found on one of the islands, and Cassytha was seen on the Colson ridge. The amount of growth on shingle bars has been much less than on sand ridges, probably as a result of the greater permeability and also mobility of the former. Ipomoea was not found in this habitat, nor were the herbs characteristic of cay surfaces under woodland.

4. Colonization of rubble and shingle spreads.

Carpets of coarse sediments deposited by the hurricane were formed on several of the Turneffe cays (Pelican, Cockroach V, Soldier, Deadman II, Deadman IV) and at Half Moon Cay, either banked against vegetation or in leeward locations. Tournefortia gnaphalodes was found in 1965 colonizing this habitat on all the islands listed, forming bushes 2-4 feet high and up to 30 feet in diameter. Sesuvium portulacastrum was found in four cases, Euphorbia in three, and Sophora, Ipomoea, Cyperus, Sporobolus and Suriana in two. Six other species were also seen, none of them common, and some, such as Hymenocallis, surviving from the pre-hurricane vegetation under a thin carpet of rubble.

5. Colonization of stripped surfaces.

The most common pioneer habitat prepared by Hurricane Hattie was the surface stripped of vegetation and superficial sediments, covered with exposed roots, particularly of coconuts, and lightly scattered with coral rubble. Because of the loss of soil, colonization of these stripped surfaces has been much slower than on constructional surfaces, and in 1965 many were still conspicuously bare. Regrowth was greatest where stripping had been least severe and where some of the pre-storm surface and vegetation survived. Stripping and colonization were noted on twelve sandy islands (Ambergris, Caulker, Chapel, St. George's, Big and Little Calabash, East I, Deadman I, Deadman V, Sandbore, Northern and Long Cays) and three shingle islands (Cockroach, Soldier, Half Moon). Direct comparison is difficult because of the differences in exposure and degree of stripping (varying from complete to narrow marginal stripping), but the colonizing species are distinct from those of other habitats. The most widespread colonizers in 1965 were Euphorbia (E. mesembrianthemifolia, also E. blodgettii), seen on 12 of the 15 islands mentioned, and Tournefortia gnaphalodes, found on 10. The bushes of Tournefortia vary in height from 1-3 feet and in diameter up to 30 feet, with their greatest development on Half Moon Cay. Other shrubs present were Borrichia arborescens, up to 6 feet tall, on 8 cays; Suriana maritima, up to 6 feet tall, on 7 cays; and Conocarpus erecta and Sophora tomentosa, each on three cays but only as scattered individuals. Borrichia is most characteristic of sandy islands on the atolls rather than the barrier reef. Ground-layer species present on six or more of the fifteen cases studied are Sesuvium, Wedelia, Ageratum, Ipomoea, Sporobolus, Cyperus and Ernodea; and at least 18 other colonizing species have been noted. The pioneer vegetation of stripped surfaces is therefore a diverse assemblage dominated by Tournefortia and Euphorbia, with Borrichia and Ageratum, and containing many of the elements of mature cay vegetation. The importance of Tournefortia by comparison with Suriana is striking; Tournefortia clearly occupies the niche filled in the Indo-Pacific by Scaevola. Tournefortia is mainly a shoreline plant, though on stripped cays found all over the surface, whereas Borrichia is generally found away from shores.

6. Intertidal and subtidal habitats.

Little attention could be paid to the vegetation of marine habitats in 1965. No change was apparent in the Thalassia meadows, where holes and channels eroded in 1961 still survive, clearly outlined by the absence of turtle grass. Intertidal beachrock, which lost its profuse

growth of _Turbinaria turbinata_ and other species during the storm is still bare of larger algae. Subtidal broken coral and rubble have been colonized by _Padina_ and other algae, and encrusting pink algae are widespread.

Recovery

1. Recovery of littoral woodland.

The littoral woodland of Cordia _sebestena_ and _Bursera simaruba_ at Half Moon Cay and Pelican Cay was badly damaged in 1961, with trees defoliated and broken but often not uprooted. In early 1962 it was often difficult to tell whether these trees were dead or alive, though individuals of _Cordia_ were seen in flower even when much broken. In 1965 virtually all the damaged _Bursera_ was dead, while _Cordia_ had made a remarkable recovery. The sea-grape _Coccoloba uvifera_ also showed a similar ability to survive massive physical damage. It is too early to predict what will happen in the dead _Bursera_ stands, which in 1965 were being overgrown at Pelican Cay by _Ipomoea tuba_. Trees such as _Thrinax_ and _Terminalia_ which survived the storm in nearshore situations were still alive in 1965.

2. Recovery of coconut thicket.

The dominant cay vegetation of neglected or naturally regenerated coconut woodland with a dense undergrowth of shrubs and ground-layer vegetation has changed (a) because of felling or decapitating of many coconuts and (b) because of at least temporary cessation of direct human interference and clearing of undergrowth. Thus thickets on many cays are much denser, with strong growths of _Borrichia_, _Tournefortia_, and to a lesser extent _Suriana_ and _Sophora_. The ground cover of _Wedelia_, _Stachytarpheta_, _Canavalia_ and other plants under cleared coconut woodland is commonly reduced by this expansion of shrubby growth. Coconuts planted or naturally germinating after the hurricane were in 1965 commonly 3-5 and exceptionally up to 10 feet tall.

3. Recovery of mangrove.

Mangrove damage in 1961 was greatest in the area of maximum storm surge and wave action, and was much less severe in areas affected only by wind. On small mangrove islands defoliation was total in a zone 25 miles wide centered on the storm track, and rare at distances of 30-40 miles from the storm track. Size of island affected the degree of damage: living mangroves were seen in 1962 on the lee sides of large islands such as Cross Cay, only 12 miles from the storm center, and defoliation was less complete in the interior of the Turneffe lagoon mangroves. Whether the mangroves defoliated by the storm were dead in 1962 was not apparent at that time.

In 1965 the defoliated mangroves in the zone of greatest damage were clearly dead (Figure 15). On the barrier reef itself, the first relatively undamaged mangrove island north of the storm track is Cangrejo Cay, south of Ambergris Cay, about 27 miles north of the storm center; and the first undamaged island to the south is Crawl Cay, 25 miles south of the storm track. Local exposure is, of course, important in determining details of mangrove damage: for example, damage was more intense

at Bugle Cay, four miles farther from the storm center, than at Crawl Cay. The transition between relatively little and relatively complete defoliation is sharp: the zone of mangrove death so enclosed has a width of 50-60 miles.

Within the limit of major defoliation a distinction can be made between areas with living mangroves in sheltered locations and areas where destruction was complete. Large patches of living mangrove are found on the west side of Cay Chapel and Cay Caulker, 20 miles north of the storm track, and at Tobacco Range, the same distance to the south. Within 20 miles of the storm track, however, damage to barrier reef mangroves was total except for very small leeward patches on the largest islands. No mangroves at all survived within a mile or two of the storm center (Middle Long Cay, Stake Bank).

On Turneffe all mangroves were killed on the small eastern sand cays, such as the Cockroach Cays, and all died along the east coast of the "main" except in sheltered places, for example near Calabash Cays. Patches also survive along the sides of some of the western entrances to Northern and Southern Lagoons. From the air there is a marked contrast between the dead mangrove and the green sandy areas where recovery of grasses, herbs and shrubs has been rapid. In the interior of the wider land areas surrounding the lagoons damage was less severe, and in places these areas are quite green. These inland locations have not been studied on the ground but from the air they appear to have a dry-land vegetation with *Thrinax* rather than mature mangrove woodland. On Lighthouse Reef patches of mangrove survive in sheltered places on Northern Cay and Long Cay, but otherwise all mangroves are dead.

The zones of mangrove damage thus defined are shown in Figure 15. Both *Rhizophora* and *Avicennia*, when dead, retain tenacious root holds, and their hard roots and branches are difficult to clear. Recolonization of these areas is thus difficult, and the drabness of the dead mangrove contrasts markedly with the green of sand and shingle cays in the damaged areas. Lack of seedlings for regeneration also delays redevelopment: few seedlings were seen in 1965 anywhere in the damaged area, where previously they had been abundant. Regrowth may also be delayed by fire: considerable areas were burning on the east side of Turneffe in April 1965, though by destroying the dead woody vegetation this may clear the ground for colonization by other plants.

Craighead and Gilbert (1962), discussing the effects of Hurricane Donna in southern Florida in 1960, have also described widespread destruction of mangroves, averaging 25-75 per cent over large areas and locally reaching 90 per cent. They state that defoliation alone is not a sufficient cause of death, since some trees put forth new leaves and suggest mechanical damage, root damage, and oxygen deficiency resulting from marl deposition as additional causes. They found, as on Turneffe, that on slightly higher areas covered with buttonwood hammock, damage was very much less than on coastal mangroves. The Mauritius cyclones apparently caused little damage to mangroves (Sauer 1962), but damage comparable to that seen in British Honduras was reported by Gleghorn (1947) from the northern Great Barrier Reef, following a cyclone in

December 1943. There is little information on mangrove recovery in reef areas following storm damage. The 1934 cyclone at Low Isles caused mechanical damage to larger trees and defoliation of small ones (Moorhouse 1936); but a decade later no sign of the damage could be seen (Fairbridge and Teichert 1947). In British Honduras the flourishing mangroves of 1959-1961 had probably developed since 1931. Near Punta Gorda, where mangroves are lower than elsewhere, they may have developed largely since the major hurricane of 1945.

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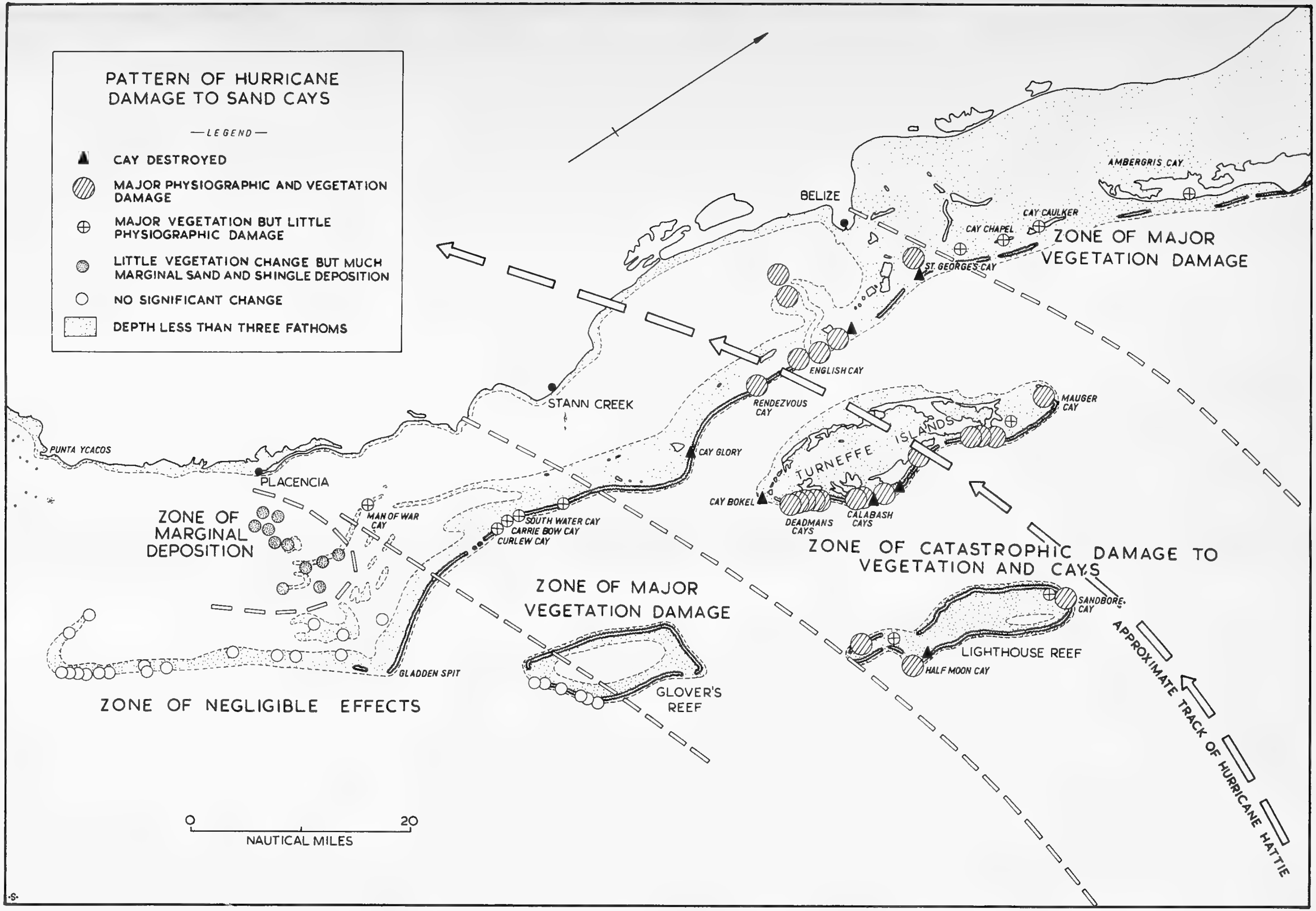
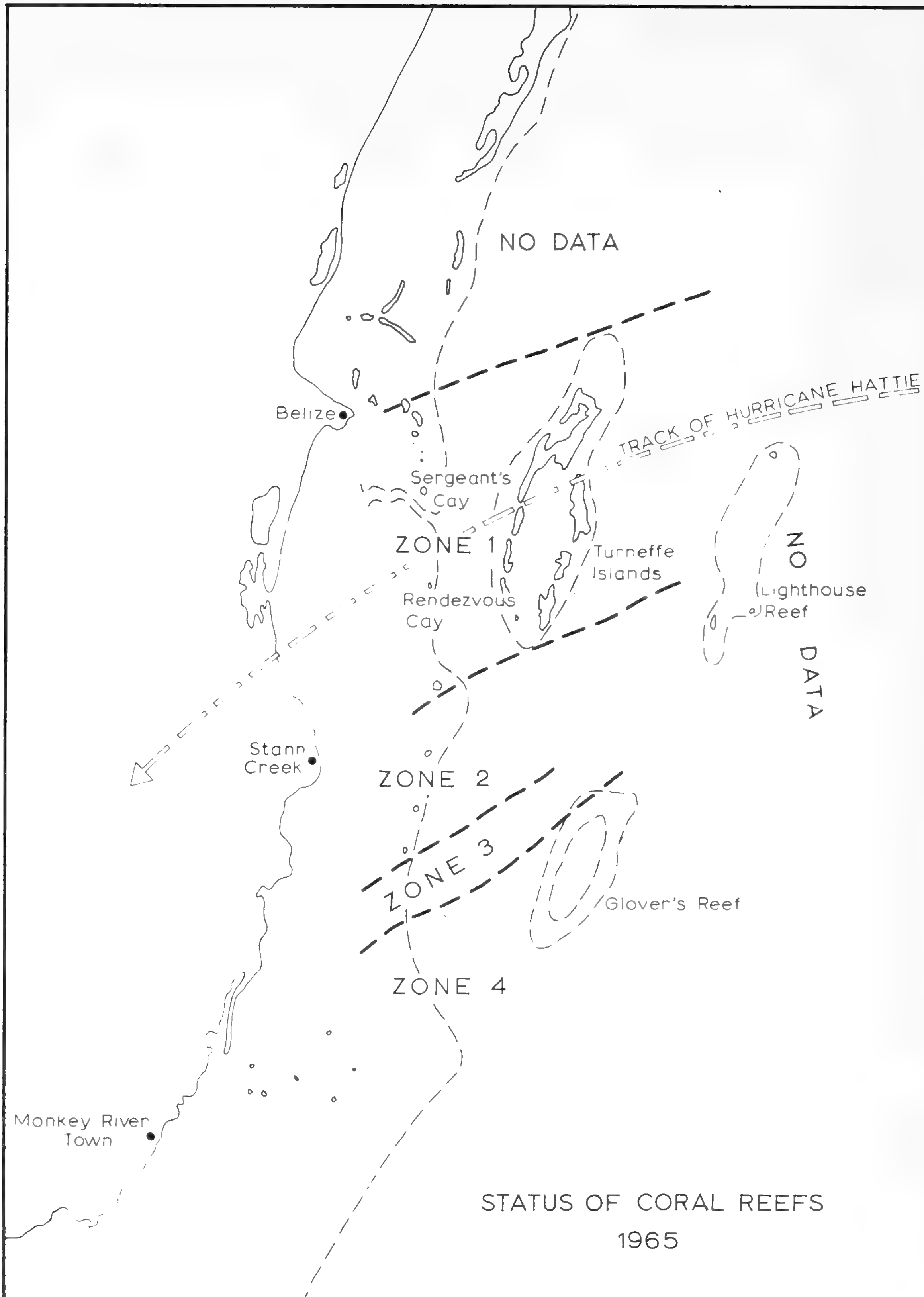
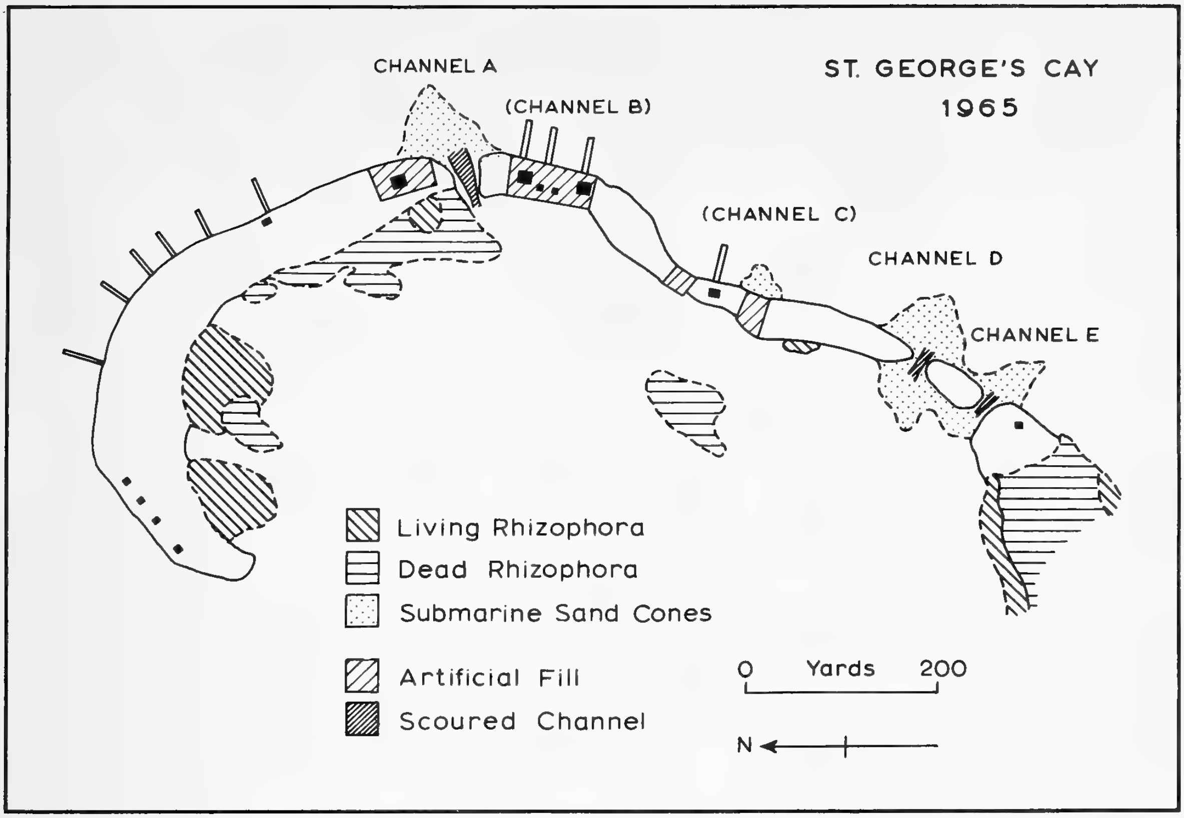


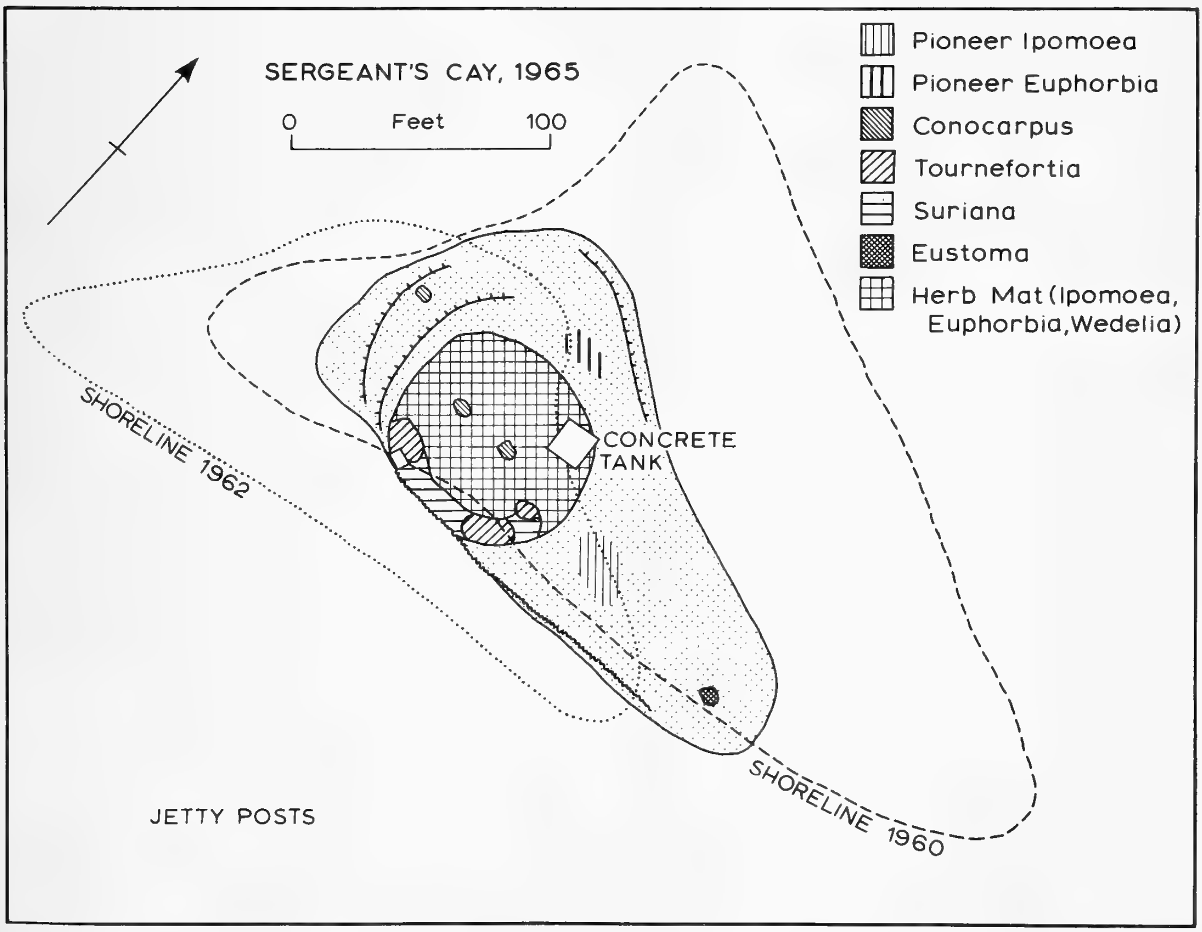
1 Pattern of hurricane damage to sand cays (from ARB 95, Fig. 62)



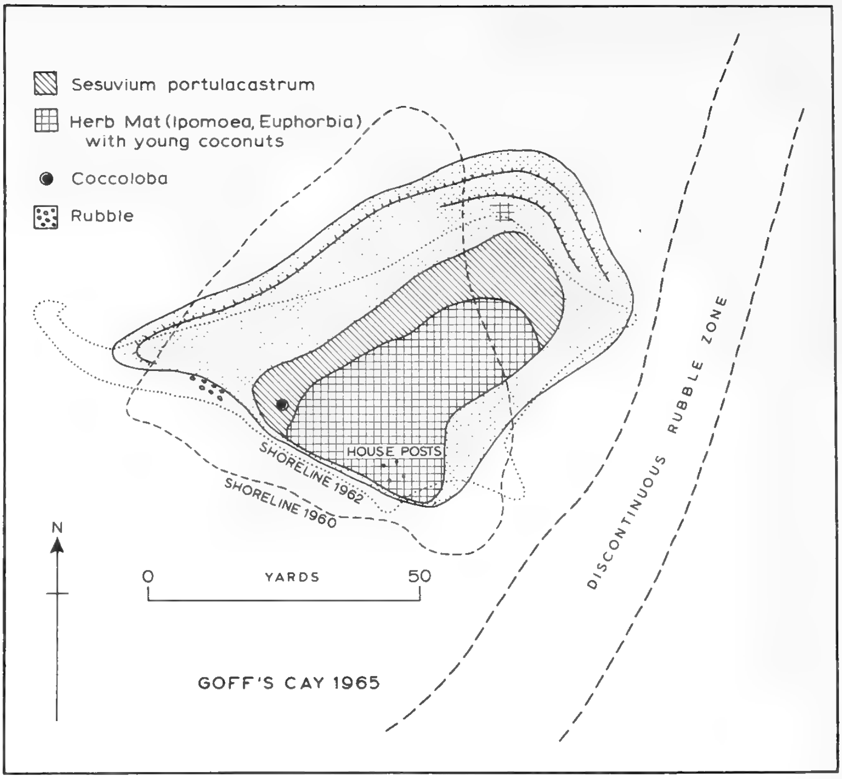
2 Status of coral reefs 1965



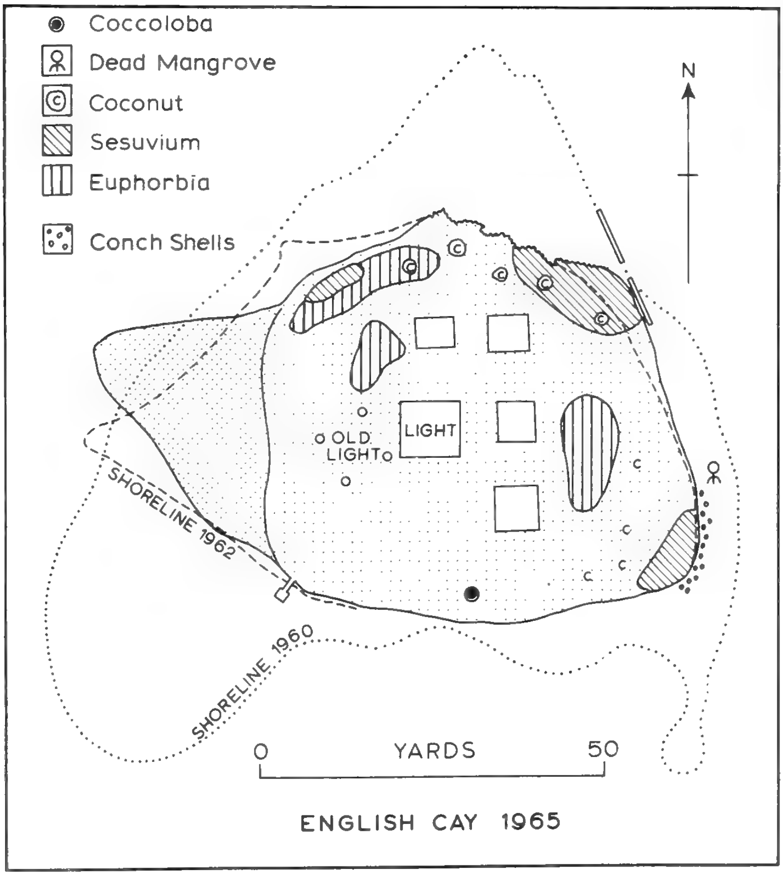
3 St. George's Cay 1965



4 Sergeant's Cay 1965

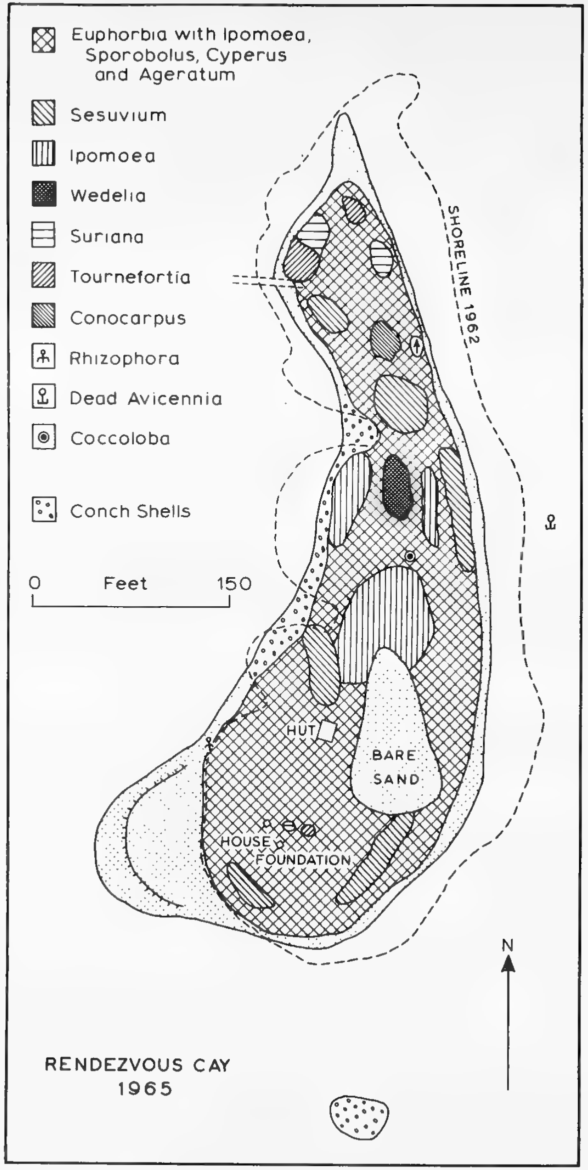


5 Goff's Cay 1965

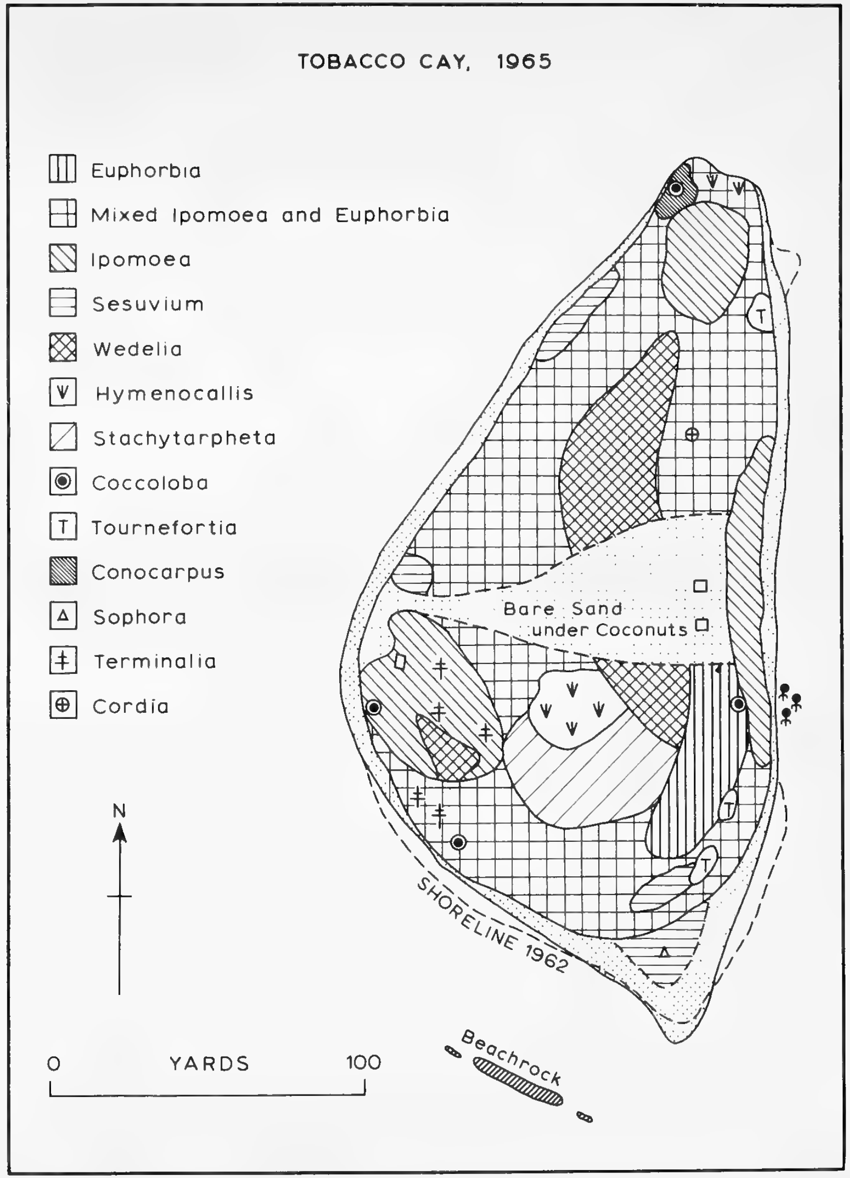


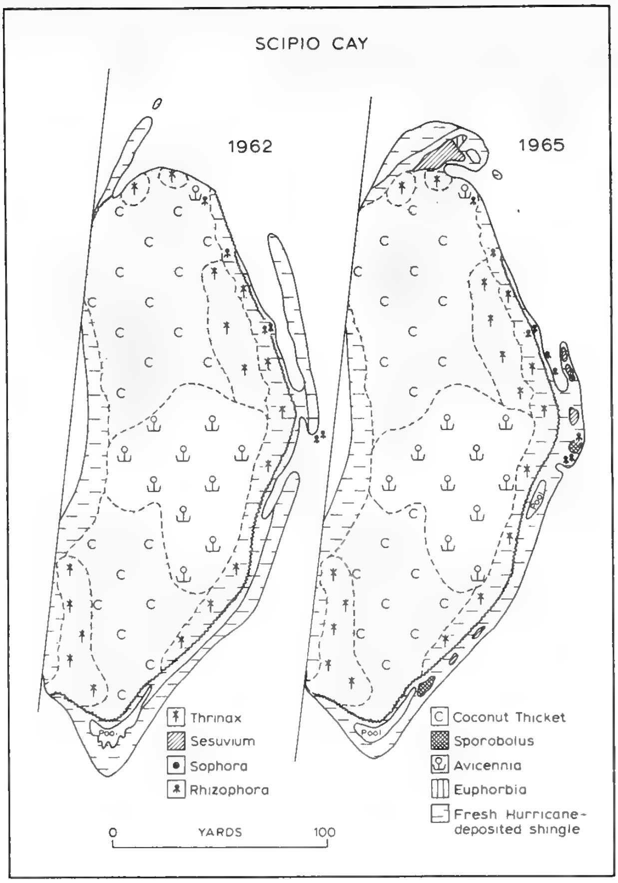
6 English Cay 1965

7 Rendezvous Cay 1965



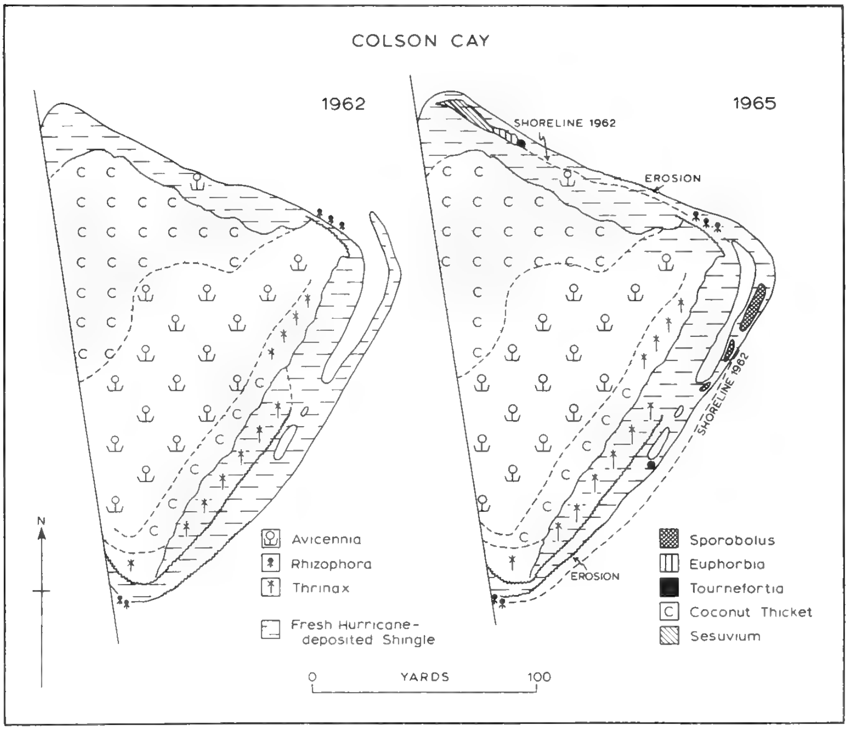
8 Tobacco Cay 1965

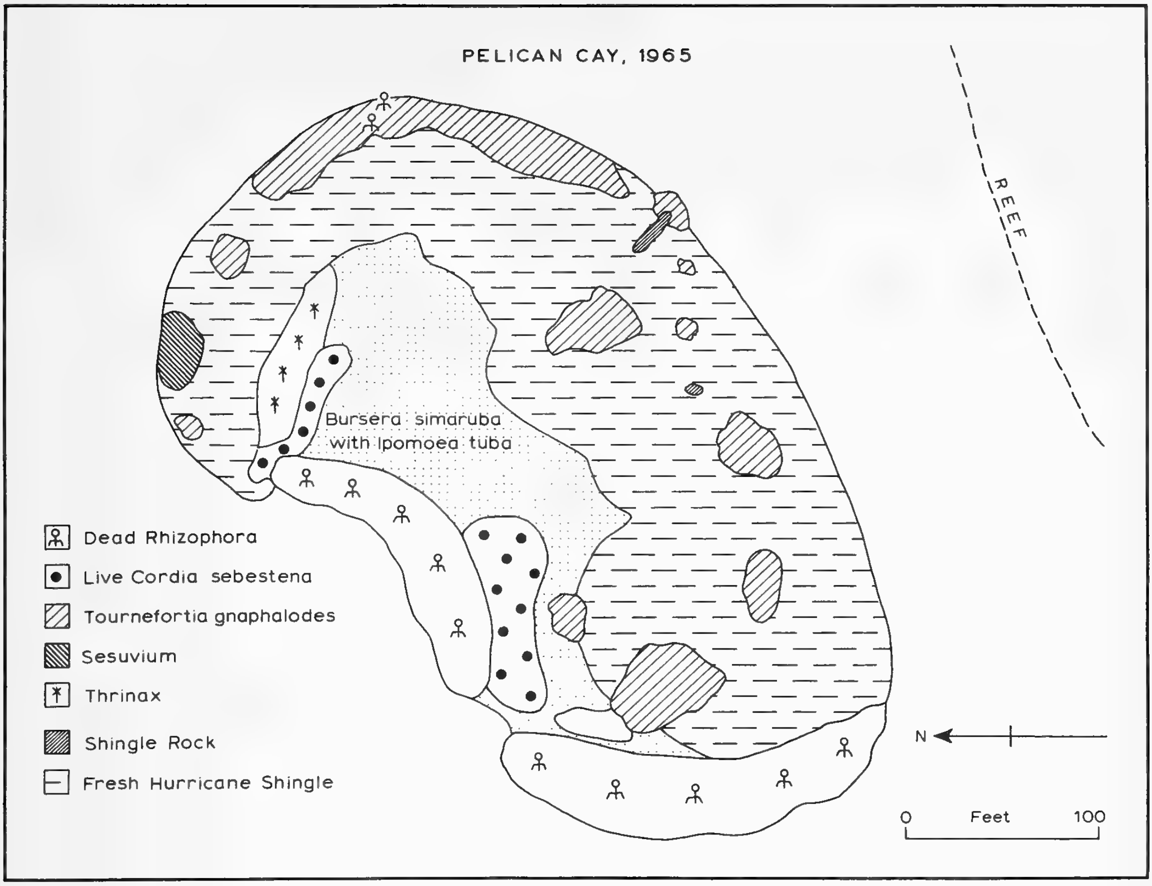




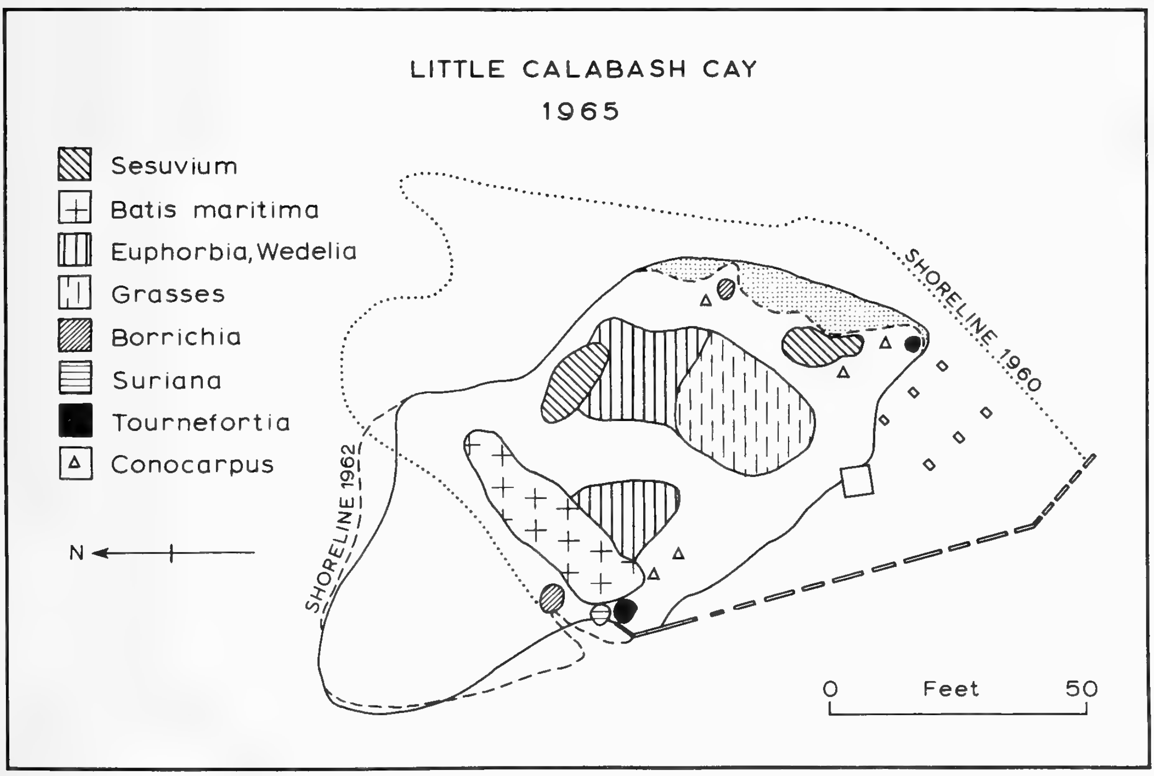
9 Scipio Cay 1962 and 1965

10 Colson Cay 1962 and 1965

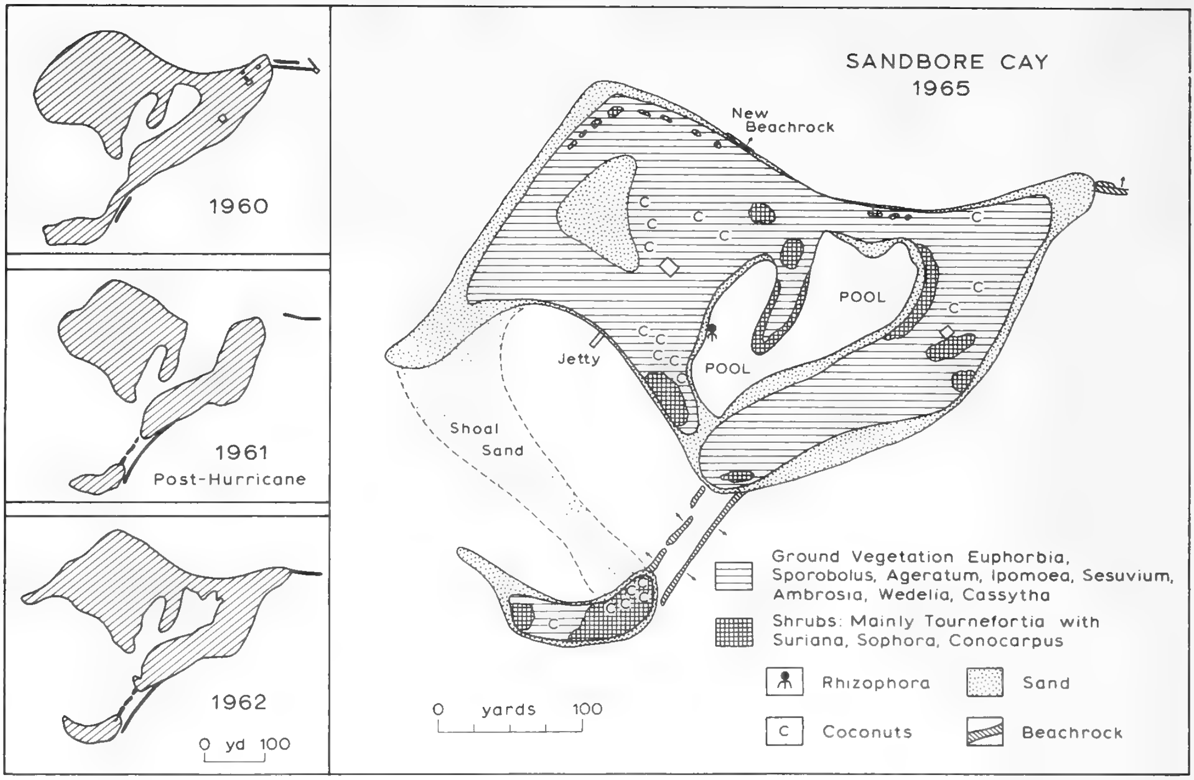




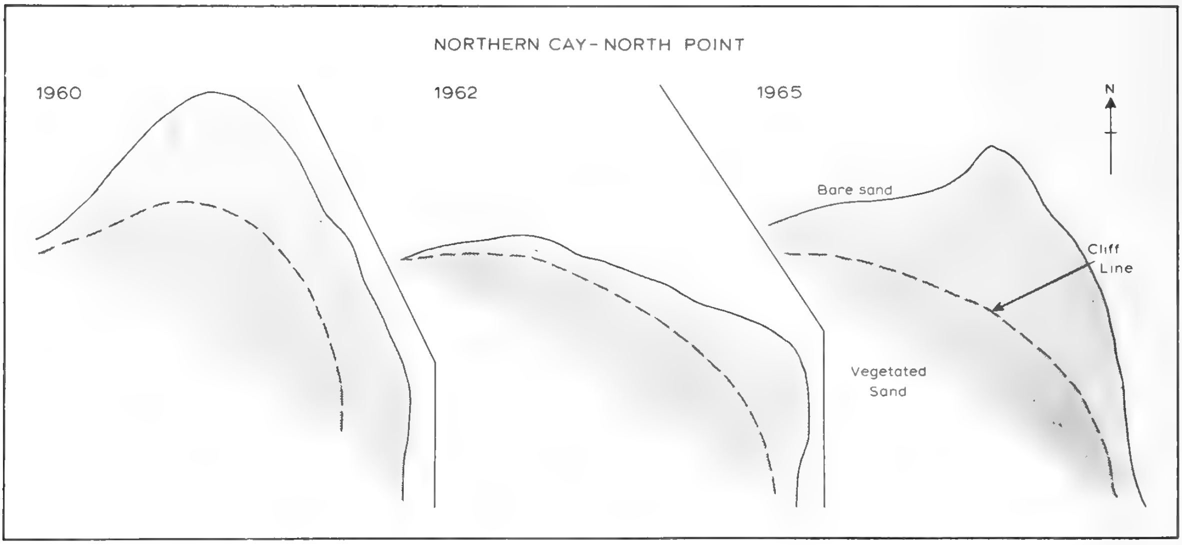
11 Pelican Cay 1965



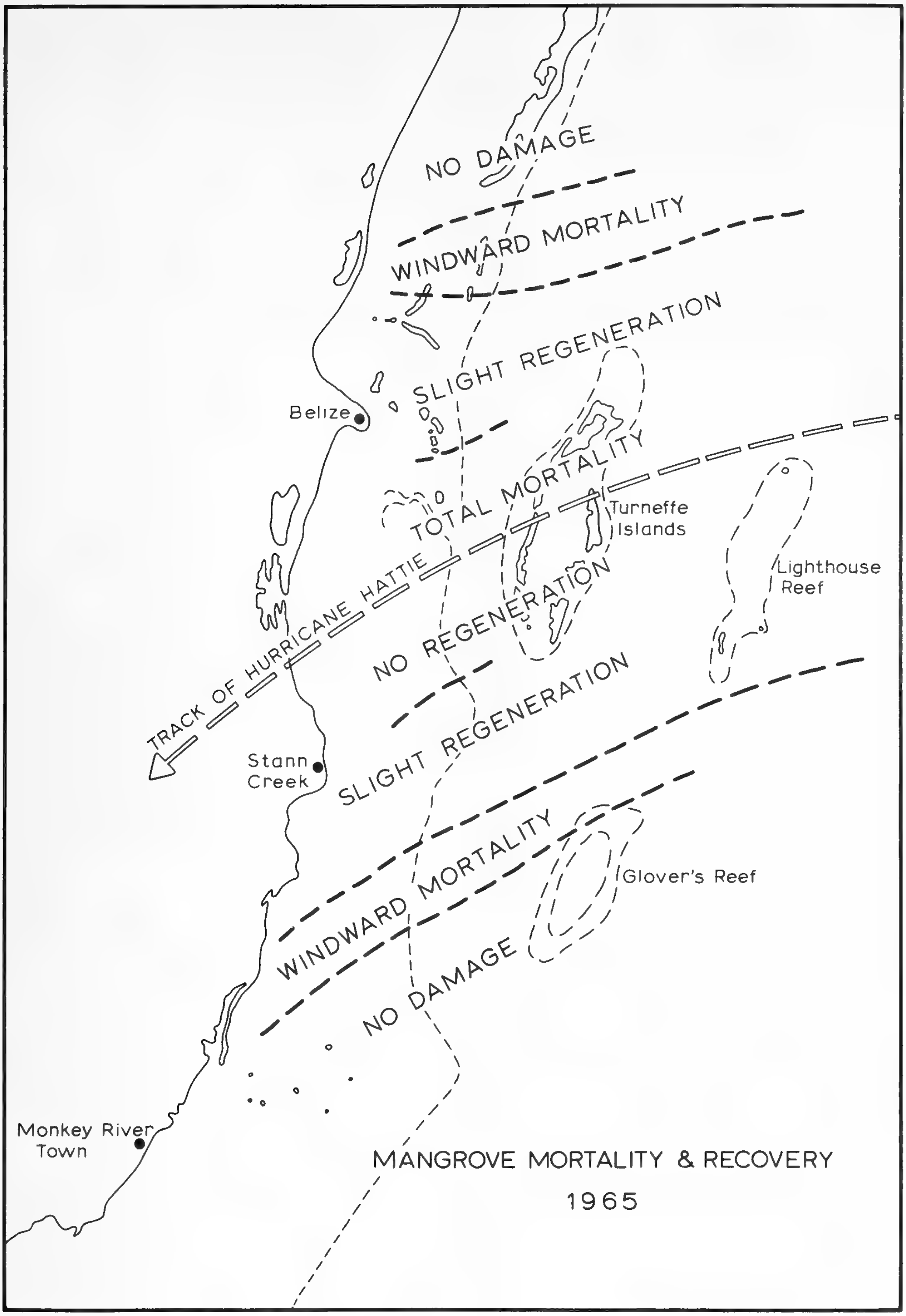
12 Little Calabash Cay 1965



13 Sandbore Cay 1965



14 Northern Cay north point 1960, 1962, 1965



15 Mangrove mortality and recovery 1965

ATOLL RESEARCH BULLETIN
NO. 132

PLANTS OF SATAWAL ISLAND, CAROLINE ISLANDS

by F. R. Fosberg

Issued by

THE SMITHSONIAN INSTITUTION

Washington, D. C., U. S. A.

August 15, 1969

PLANTS OF SATAWAL ISLAND, CAROLINE ISLANDS

by F. R. Fosberg

Satawal is a small flat coral island in the west central Caroline Islands about 1050 km east-south-east of Yap Island, at latitude 7°21' N, longitude 147°02' E. Although its surface is locally somewhat irregular, its greatest height is not more than about 4 meters above mean low water. Its long axis is about east-west and its area is 1.3 square km. It is surrounded by a fringing reef upward of 100 meters wide. It has no lagoon, so would be classified according to Tayama's scheme as a table reef. From the viewpoint of land ecology it is an atoll. The substratum varies from sandy to boulders, with some peat very locally. The beaches are sandy around the western half, of pebbles and cobbles around the eastern half.

The island is almost entirely wooded--only a small grassy clearing that serves as a school playground, an area of scrub on the extreme east end and a tiny scrub-covered mangrove depression near the east end are not forested. Most of the forest is coconut plantation, with an open understory of small trees and shrubs. Above this, in much of the central part, rise enormous emergent breadfruit trees. Many of these have great buttressed trunks 1 meter or more in diameter. Emergent trees are lacking or nearly so in a peripheral zone 100 meters or more wide, especially on the south side. The village is located on the north side. In it the coconuts are less dense and there are many ornamental trees and shrubs. The undergrowth in the forest varies in aspect and composition locally, but everywhere ferns are very abundant, mostly terrestrial but also epiphytic. Mosses are abundant on both rocks and tree-trunks. The most common understory small trees and shrubs are Morinda citrifolia, Premna obtusifolia, Crateva speciosa, Pipturus argenteus, and young coconuts. Locally the gigantic leaves of Alocasia macrorrhiza and of Musa sapientum are conspicuous. There are no extensive taro swamps, although in a few deep small pits Cyrtosperma is growing well enough. Vines are so abundant as to give a luxuriance to the landscape over and above that due to the prevalence of ferns. Among them are Vigna marina, Wedelia biflora, Piper ponapense, Piper fragile, and, less common, Canavalia cathartica and Ipomoea indica.

Along the north beach in front of the village, Pandanus tectorius is common, with a few Casuarina equisetifolia.

Along the south coast the coconut trees come to the beach, but sparser and smaller here. There is a strip of scrub forest of somewhat drier aspect than that farther inland, with Morinda citrifolia, Scaevola taccada, Tournefortia argentea, Pipturus argenteus, Terminalia samoensis,

a few Cordia subcordata, as well as low coconut trees. Triumfetta procumbens, Vigna marina, Thuarea involuta and Polypodium scolopendria cover the ground.

Toward the east end of the island this forest is more prevalent, and has Guettarda speciosa, occasional Pisonia, Ficus tinctoria, and rarely, Hernandia sonora. Away from the beach this becomes more mesophytic and has some breadfruit. Ferns are abundant. Here coconut plantings are less continuous. Small groves of Pisonia grandis and of Eugenia javanica are found. Near the east end is a tiny mangrove depression, with deep peat, a few Bruguiera gymnorhiza trees, and a dense tangle of Acrostichum aureum and Clerodendrum inerme 2-3 meters tall. Near the south shore, toward the east end, are occasional Pandanus dubius trees, but usually small, sterile, and not more than 4 meters tall. Hernandia is occasional here, too.

The extreme east end is covered by a dense scrub of Scaevola taccada and Clerodendrum inerme 2-3 meters tall, with scattered larger, very much battered trees of Tournefortia argentea and a few tall coconuts. A dense fringe of Scaevola and Tournefortia, with a few scattered Pemphis acidula and Pandanus tectorius, edged with Vigna marina and Triumfetta procumbens lines the top of the beach around the whole except in front of the village.

The village and the people are among the most attractive in Micronesia. The houses are Micronesian in style and materials, galvanized iron being seen only in the church. The people are friendly and appear very healthy. They live on breadfruit, coconuts, taros of several sorts, chicken, pork and fish. They export copra when there is an opportunity. Their contact with the outside is somewhat less than that of most Micronesians because of the relatively difficult landing over the reef. They do not appear less happy or less well-off because of this.

A small list of plants, apparently unsupported by specimens, was published by Damm, H., in Thilenius, Erg. Südsee Expedition II, B, 6, 2: 15-16, 1935. These are cited as appropriate in the text.

The collections listed below were made during parts of two days spent on the island in August 1965. They probably represent the flora rather completely though some species may have been missed. The local names are from many informants, though the majority were supplied by Ignacio. The people generally seem very familiar with the plants of the island. Species presumed to be introduced by human agency are indicated by an asterisk *. Specimens cited have not been distributed, as they must still be studied for the flora of Micronesia. Some of them are not in good condition and may have to be discarded.

POLYPODIACEAE

ACROSTICHUM AUREUM L.
Abundant in mangrove depression near east end, Fosberg 46940; "epéu."

ASPLENIUM NIDUS L.
Occasional to common, terrestrial or rarely epiphytic in forest sites, Fosberg 46895; "cherluk" or "reluk."

ATHYRIUM BLUMEI (Bergstr.) Copel.
Common in dense forest in central part, uncommon elsewhere in forests, terrestrial, Fosberg 46906, 46944; "sivilkuel."

NEPHROLEPIS BISERRATA (Sw.) Schott
Common to abundant generally in forests, terrestrial or less commonly epiphytic on tree trunks, Fosberg 46909, 46934; "amărei." Damm, p. 16, as *N. acuta*.

POLYPODIUM SCOLOPENDRIA Burm. f.
Abundant generally, terrestrial or epiphytic on bases of trees, Fosberg 46911; "rir'ri."

PTERIS TRIPARTITA Sw.
Occasional generally in forests in more moist sites, Fosberg 46904; "sivilkuel."

PANDANACEAE

PANDANUS DUBIUS Spreng.
Occasional shrubs or small trees in forest, especially near north side, all seen sterile, Fosberg 46903; "pogu."

PANDANUS TECTORIUS Park.
Occasional, especially along north beach, Fosberg 46936; "fach"; fruit said not to be eaten. Damm, p. 15, as *Pandanus*.

GRAMINEAE

*CENCHRUS BROWNII R. & S.
Locally common in open places and just back of beaches, Fosberg 46874; "ălū."

DIGITARIA PRURIENS (Trin.) Buse var.
Local along paths, Fosberg 46892.

*ELEUSINE INDICA (L.) Gaertn.
Abundant in village and along paths, Fosberg 46868; "puker."

*ERAGROSTIS TENELLA (L.) Beauv.
Very local in open spots in village and in school playground, Fosberg 46872; "buruak."

LEPTURUS REPENS R. Br. var. REPENS
Local, usually just back of beach, Fosberg 46848; "fetil." This has rather thicker rachis than usual and approaches var. occidentalis, but the glumes are only 6-10 mm long.

*PASPALUM CONJUGATUM Berg.
Local along paths in village and forest, Fosberg 46893.

*SACCHARUM OFFICINARUM L.
Not seen by us, but reported by Damm, p. 15, as Zuckerrohr."

THUAREA INVOLUTA (Forst. f.) R. & S.
Common generally, especially along paths and back of beaches, Fosberg 46850, Fosberg 46892a; "fetilupuai"; in dense breadfruit forest, sterile.

*ZOYSIA TENUIFOLIA Trin.
Locally common in village, forming dense mats, Fosberg 46864; "fetil."

CYPERACEAE

*CYPERUS BREVIFOLIUS (Rottb.) Hassk.
Very local in inner part of village, Fosberg 46875; "fithin nar."

FIMBRISTYLIS CYMOSA R. Br.
Locally common, usually just back of beach, Fosberg 46849; "pukarangas."

ARACEAE

*ALOCASIA MACRORRHIZA (L.) Schott
Very common around village and in parts of the forest near village, Fosberg 46869; "filĕ." Damm, p. 15, as "Taro-Art mit groszen Knollen."

*COLOCASIA ESCULENTA (L.) Schott
Commonly planted on dry land, especially around village, Fosberg 46863; "wot omalu"; corms used as food. Damm, p. 15, as "kleine Taro-Art."

*CYRTOSPERMA CHAMISSONIS (Schott) Merr.
Planted in deep pits in forest, not abundant, Fosberg & Evans 46894; "pulá." Damm, p. 15, as Cyrtosperma.

*XANTHOSOMA SAGITTIFOLIUM (L.) Schott
Planted in village, Fosberg 46870; "yigalulu."

*XANTHOSOMA VIOLACEUM Schott
Planted in village, occasionally spontaneous in nearby forest; Fosberg 46912; "Honolulu cha."

PALMAE

*COCOS NUCIFERA L.
Dominant tree in almost all parts of island, planted and spontaneous, Fosberg 46952; "nu" "ŭlŭ" (flowers). Trunks and leaves furnish most of the building materials; fiber of husks used for cordage; water of green husks as well as fermented sap for drinking, nut meat for food; husks for fuel; meat of nuts dried and exported as copra. Damm, p. 15, as "Kokospalme."

AMARYLLIDACEAE

*HYMENOCALLIS LITTORALIS (Jacq.) Salisb.
Common around village and near paths in forest, Fosberg 46886; "lirio."

*ZEPHYRANTHES ROSEA (Spreng.) Lindl.
Planted in gardens, Fosberg 46862.

DIOSCOREACEAE

DIOSCOREA BULBIFERA L.
Occasional in forest, Fosberg 46898; "pelai."

TACCACEAE

*TACCA LEONTOPETALOIDES (L.) O. Ktze.
Occasional, spontaneous in forests generally, Fosberg 46913; "mokumok" or "mogumog."

MUSACEAE

*MUSA SAPIENTUM L.
Planted in forest around village, not collected. Damm, p. 15, as "Banane."

ZINGIBERACEAE

*HEDYCHIUM CORONARIUM Koen.
Seen only as "marumar" or garland, obviously growing in or near village, Fosberg 46935.

CASUARINACEAE

*CASUARINA EQUISETIFOLIA L.
One tree, back of beach in front of village, probably planted, Fosberg 46851; "ueuhir."

PIPERACEAE

PIPER FRAGILE Benth.
Common in the wet forests dominated by breadfruit trees, creeping on ground and climbing trees, Fosberg 46907; "atobuei."

PIPER PONAPENSE C. DC.
Common in the wet forests dominated by breadfruit trees, mostly climbing, Fosberg 46897; "elek."

MORACEAE

ARTOCARPUS ALTILIS (Park.) Fosb.
One of dominant trees in central forests, reaching a great size, Fosberg 46908; "mai." Trunks used for canoe-building and house posts; fruit a principal food. Damm, p. 15, as "Brotfrucht, kernlose Art."

ARTOCARPUS MARIANNENSIS Tréc.
One of the dominant trees in the central forest, reaching great size, Fosberg 46946; "mai." Damm, p. 15, as "Brotfrucht, kernreiche Art."

FICUS TINCTORIA Forst. f.
Common as a shrub in the central forests, a small tree in the less disturbed forests toward the southeast part of island, Fosberg 46899; "awan," "awal."

URTICACEAE

LAPORTEA RUDERALIS (Forst. f.) Chew (*Fleurya ruderalis* (Forst. f.) Gaud. ex Wedd.)
Common on coral gravel in opener places in forest, and in village, Fosberg 46918; "afelefelegech."

*PILEA MICROPHYLLA L.
Very local on bare coral gravel in village, Fosberg 46900; "seling."

PIPTURUS ARGENTEUS (Forst. f.) Wedd.
Occasional to common in understory in forest, Fosberg 46905; "aróma." Damm, p. 15, as *P. incanus*.

NYCTAGINACEAE

*MIRABILIS JALAPA L.
Planted around dwellings, <u>Fosberg 46856</u>; "flores."

PISONIA GRANDIS R. Br.
Occasional in forest in east end of island, <u>Fosberg 46943</u>; "moek."

AMARANTHACEAE

*ACHYRANTHES ASPERA L.
In relatively open places near village, <u>Fosberg 46914</u>; "ĕĕg'gohur."

*AMARANTHUS VIRIDIS L.
Local weed in village, <u>Fosberg 46888a</u>.

PORTULACACEAE

*PORTULACA OLERACEA L.
Common weed on bare ground in village, <u>Fosberg 46887</u>; "erkul."

PORTULACA SAMOENSIS von Poelln.
Common weed on bare ground in village, <u>Fosberg 46860</u>; "ōp."

LAURACEAE

CASSYTHA FILIFORMIS L.

Common generally, especially near beaches; parasitic on many hosts, <u>Fosberg 46842</u>; "tig."

HERNANDIACEAE

HERNANDIA SONORA L.
Rare tree in forests near beaches, one seen in village, <u>Fosberg 46948</u>, <u>46883</u>; "orang."

CAPPARIDACEAE

CRATEVA SPECIOSA Volk.
Very common understory tree in forests, <u>Fosberg 46890</u>; "afur."

LEGUMINOSAE

*CAESALPINIA PULCHERRIMA (L.) Sw.
Planted in village, <u>Fosberg 46853</u>; "waripik."

CANAVALIA CATHARTICA Thou. (C. microcarpa DC.)
Locally common in forests, climbing in trees, Fosberg 46938, 46844; "walima."

*LEUCAENA LEUCOCEPHALA (Lam.) de Wit
One seedling found in rather open place in forest, Fosberg 46922; "tangan-tangan."

MUCUNA GIGANTEA (Willd.) DC.?
One seedling found along south beach, Fosberg 46933.

SOPHORA TOMENTOSA L.
Rare, back of beach at west end, Fosberg 46932; "kolu" or konu."

VIGNA MARINA (Burm.) Merr.
Common to abundant, generally except in densest forests, Fosberg & Evans 46840; "ōlū."

RUTACEAE

*CITRUS AURANTIFOLIA (Christm.) Swingle
Planted in village, Fosberg 46857; "lemon." Damm, p. 16, as Limone.

EUPHORBIACEAE

EUPHORBIA CHAMISSONIS (Kl. & Gke.) Boiss.
Common locally in forest back of south beach, Fosberg 46846; "echich."

*PHYLLANTHUS AMARUS Schum. & Thon.
Common in village and along paths, Fosberg 46871; "walpachi."

TILIACEAE

TRIUMFETTA PROCUMBENS Forst. f.
Common at top of and back of south beach, Fosberg 46845, Fosberg & Evans 46951; "ara."

MALVACEAE

*HIBISCUS ROSA-SINENSIS X SCHIZOPETALUS ?
Rare, planted in forest near center of island, Fosberg 46896; "pue tal."

HIBISCUS TILIACEUS L. Occasional in village and nearby parts of forest, Fosberg 46884; "kilifu." Damm, p. 16, as Hibiscus.

CARICACEAE

*CARICA PAPAYA L.
Occasional, especially in village and along paths in forest, not collected.

CUCURBITACEAE

*CUCURBITA MAXIMA L.
Planted in village and nearby semi-open places, Fosberg 46876; "calamasa."

LYTHRACEAE

PEMPHIS ACIDULA Forst. f.
Several bushes along east end of south beach, Fosberg 46950; "engi." Damm, p. 16, as "Strauch," "ani."

RHIZOPHORACEAE

Bruguiera gymnorhiza (L.) Lam.
Several trees in mangrove depression at east end, Fosberg 46941; "yong." The form with pink calyces. ? Damm, p. 15, as "Mangrove."

LECYTHIDACEAE

BARRINGTONIA ASIATICA (L.) Kurz
Rare tree in forest just back of beach in east part of island, Fosberg 46947; "kul."

COMBRETACEAE

TERMINALIA SAMOENSIS Rech.
Common in scrub and forest back of south beach, Fosberg 46843; "kil."

MYRTACEAE

EUGENIA JAVANICA Lam.
Very local in forest, Fosberg 46937; "fariap."

ARALIACEAE

*POLYSCIAS FRUTICOSA (L.) Harms
Planted in village, Fosberg 46859; "yobung."

GENTIANACEAE

FAGRAEA BERTERIANA A. Gray ex Benth.
Not seen by us, but Damm, p. 16, reports a "Fragraea."

APOCYNACEAE

OCHROSIA ELLIPTICA Labill.?
Sparingly planted in village, Fosberg 46882; "langet." This ornamental is scarcely known from Micronesia. The fruit was immature when collected and the determination is not positive.

CATHARANTHUS ROSEUS (L.) G. Don
Common in village, Fosberg 46867; "pueopuech."

CERBERA sp.
Not seen by us, but reported by Damm, p. 16, on Krämer's authority, with the vernacular name, "uma."

*PLUMERIA RUBRA L.
Occasional in village, Fosberg 46885; "seu."

*TABERNAEMONTANA DIVARICATA (L.) R. Br.
Sparingly planted in village, Fosberg 46858; said to have been recently introduced from Ulithi.

ASCLEPIADACEAE

*ASCLEPIAS CURASSAVICA L.
Planted or subspontaneous in village, Fosberg 46877; "margarita" or "pugarigarita."

CONVOLVULACEAE

*IPOMOEA BATATAS (L.) Lam.
Planted in village, Fosberg 46866; "komote."

IPOMOEA INDICA (Burm.) Merr.
Local in semi-openings in forest, Fosberg & Evans 46917; "walikurd."

IPOMOEA LITTORALIS Bl.
Occasional near paths in forest, Fosberg 46919; "raiwal."

IPOMOEA PES-CAPRAE (L.) R. Br.
One tiny seedling found on south beach, Fosberg 46949.

BORAGINACEAE

CORDIA SUBCORDATA Lam.
Occasional in forest back of the south beach, Fosberg 46847; "alu." Damm, p. 16, as *Cordia* (Karolinenpappel), mok, quotes Krämer as reporting "eine andere Art 'galie'."

TOURNEFORTIA ARGENTEA L. f.
Common in forest and scrub along beaches, Fosberg 46839; "chel." This population has rather wider leaves than usual, rounded at apex.

VERBENACEAE

CALLICARPA CANDICANS (Burm. f.) Hochr.
Locally common in undergrowth in forest at extreme east end of island, Fosberg 46942; "ligitar." Pacific plants are often referred to as *C. erioclona* Schauer.

CLERODENDRUM INERME (L.) Gaertn.
Abundant in scrub and in mangrove depression at east end, occasional elsewhere near beaches, Fosberg 46852; "aupui."

CLERODENDRUM SPECIOSSIMUM van Geert
Occasional in interior forests, Fosberg & Evans 46889; "aubui vilifŭ" or "abui."

*LANTANA sp.
Not seen by us, but reported by Damm, p. 16, on Krämer's authority, with vernacular name, "tios."

PREMNA OBTUSIFOLIA R. Br.
Common generally, two forms observed: one the ordinary form, Fosberg 46891; the other with maroon stems, petioles and principal veins, Fosberg 46915, this form only seen sterile; both called "iár" or "eár." Damm, p. 16, as *P. integrifolia*.

LABIATAE

*COLEUS SCUTELLARIOIDES L.
Sparingly planted in village, Fosberg 46879; "warugucháa."

*OCIMUM SANCTUM L.
Planted in village, Fosberg 46881; "taipwo"; the form with purple inflorescence that is most common in this region.

SOLANACEAE

*CAPSICUM FRUTESCENS L.
Common in forest back of village, Fosberg 46916; "amuek."

*NICOTIANA TABACUM L.
Planted around dwellings in village, Fosberg 46888.

*SOLANUM MELONGENA L.
Sparingly planted in village, Fosberg 46865; the form with thick pyriform fruit, recently introduced.

ACANTHACEAE

BLECHUM BROWNEI f. PUBERULA Leonard
Common generally in forest and village, Fosberg 46921; "rud aner re tiwai."

*PSEUDERANTHEMUM CARRUTHERSII var. ATROPURPUREUM (Bull) Fosb.
Sparingly planted in village, Fosberg 46854; "kakive."

RUBIACEAE

GUETTARDA SPECIOSA L.
Occasional in forests back of beaches, especially toward the east end, Fosberg 46945; "muesor."

HEDYOTIS BIFLORA (L.) Lam.
Common in paths and in village, Fosberg 46873; "opusar."

MORINDA CITRIFOLIA L.
Very common generally, one of the principal shrubs and understory trees; Fosberg 46855; "leen" (lān).

GOODENIACEAE

SCAEVOLA TACCADA (Gaertn.) Roxb.
Abundant along beaches and in forest immediately back of beaches, Fosberg 46841; "lat."

COMPOSITAE

ADENOSTEMMA LAVENIA (L.) O. Ktze.
Occasional in forest, Fosberg 46910; "yoelusoek."

*ARTEMISIA VULGARIS L.
One small sterile patch seen planted in village, Fosberg 46861; "iarbwas."

*BIDENS SULPHUREUS L.
Planted and subspontaneous in sunny places in village, Fosberg 46878; "purang palap."

*VERNONIA CINEREA var. PARVIFLORA DC.

Common weed in village and nearby parts of forest, Fosberg 46880; "opusar."

WEDELIA BIFLORA (L.) DC.

Abundant almost everywhere on island except in the village and some of the densest forest, Fosberg 46920; "atiat."

Damm, p. 16, reports another identified shrub as "luk."

ATOLL RESEARCH BULLETIN
NO. 133

A COLLECTION OF PLANTS FROM FAIS, CAROLINE ISLANDS

by F. R. Fosberg and Michael Evans

Issued by

THE SMITHSONIAN INSTITUTION

Washington, D. C., U. S. A.

August 15, 1969

A COLLECTION OF PLANTS FROM FAIS, CAROLINE ISLANDS

by F. R. Fosberg and Michael Evans

Fais (Tromelin) is an elevated coral island, surrounded by interrupted cliffs 15-20 meters high, lying some 140 miles east of Yap Island, at latitude 9°46' N, longitude 140°31' E in the western Caroline Islands. It has an area of 2.8 square km, and has a population of about 300 people, Micronesians, speaking a dialect of the Ulithi-Woleai tongue. As with many such raised coral islands, valuable calcium phosphate deposits occur on Fais, the greater portion of which was removed and exported during the period of Japanese rule (1914-1945).

At present the interior of the plateau and the sand flats at the bases of the cliffs and slopes back of the beaches are used for agriculture, mostly coconut plantations, though some areas of the plateau are open and devoted to cultivation of sweet potatoes, manihot, tobacco and even Alocasia macrorrhiza.

In the coconut plantations are scattered trees and shrubs of various sorts, especially Artocarpus altilis (breadfruit), Hibiscus tiliaceus, Morinda citrifolia, Calophyllum inophyllum, Premna obtusifolia, Ochrosia oppositifolia, Randia cochinchinensis, Eugenia aquea and E. javanica. Bananas, papayas, Tacca leontopetaloides, and especially Alocasia macrorrhiza are also common, as well as various herbaceous weeds. Weeds of a number of kinds are found in the cultivated fields. Around the villages ornamental as well as edible garden plants are found in great profusion.

Much of the periphery of Fais is lined by vertical, or usually undercut, cliffs, at the top of which is a zone of very rough deeply pitted coral limestone, about level with or in places slightly higher than the main interior plateau surface. This is covered by a belt of dense low forest, principally an almost pure stand of Barringtonia asiatica. On the inland side it is mixed with a number of species of trees and large shrubs, especially Premna obtusifolia, Hibiscus tiliaceus, Pipturus argenteus, Melochia compacta, Ficus tinctoria and Morinda citrifolia. On the seaward side are thickets and patches of Pandanus tectorius, fading into a narrow scrub fringe of Tournefortia argentea and Scaevola taccada. In places this forest comes right to the cliff edge, and here, and on ledges, is a massive scrub of Pandanus dubius, extending down the cliffs where there are broken parts. On the more sheer areas of these cliffs Fimbristylis cymosa and Hedyotis albido-punctata cling to slight irregularities. In front of the forest, on some stretches of cliffed coast is an open zone of herbaceous vegetation with scattered shrubs. This zone must in its entirety be subject

to drenching by salt spray during rough weather, and even with moderately strong waves the forward parts get considerable spray. This terrace-like area is eroded to extreme roughness and sharpness, but not pinnacled. The back parts of it are covered by a mixture of low-growing Heliotropium anomalum, Hedyotis albido-punctata, Fimbristylis cymosa and Wedelia biflora, the latter much more succulent here than usual. Locally this is replaced by a pure stand of Paspalum distichum. The front, more heavily spray-affected, belt of this terrace is locally bare, but generally covered by a pure stand of dense hard tussocks of a grass, sterile at the season of this visit, but probably Sporobolus farinosa, known previously only from rough limestone in the Marianas.

The tops of the beaches, in front of the coconut area, are green with a dense mat of Vigna marina and Triumfetta procumbens.

The above observations were made during a two and one-half hour visit by the writers on July 30, 1965, while on a Trust Territory "field trip" aboard M/V ROQUE. Thanks are due Captain L. B. Roberts, master of the vessel, for lying to offshore while the visit was made; to Mr. Stephen Echin, of Ulithi, Trust Territory field trip officer, for getting the party ashore and for introductions to the people of Fais; to Mr. Santos, of Fais, who supplied the vernacular names of certain plants, and to numerous small boys who enthusiastically carried plant presses and helped collect specimens.

Since the time was limited and only a small part of the island covered, this collection in all likelihood represents only a fraction of the total vascular flora of the island. In all 120 species are listed below, including several of which collections were not made. The collections came from the southwest part of the island. Krämer, in Thilenius, Erg. Südsee-Exp. II, B, 10: 299-413, 1937, gives an account of this island, mainly ethnological, but with a list of plants, apparently unsupported by specimens. These are cited here as appropriate, where they can be identified. Species presumed to have been introduced by human agency are marked by an asterisk *. The specimens cited have not been distributed, as they must still be studied for the flora of Micronesia. Some of them are not in good condition and may have to be discarded.

POLYPODIACEAE (sensu lato)

ASPLENIUM ADIANTOIDES (L.) C. Chr.
Local on shaded cliff, Fatadol, Fosberg 46732. Even fertile plants vary enormously in stature.

NEPHROLEPIS HIRSUTULA Forst. f.
Abundant in coconut plantations on plateau, terrestrial, Fosberg 46705. Fronds mostly erect.

POLYPODIUM SCOLOPENDRIA Burm. f.
Abundant in coconut plantations on plateau, terrestrial and climbing on bases of coconut trees, Fosberg 46697.

PANDANACEAE

PANDANUS DUBIUS Spreng.
Forming dense thickets on ledges and tops of cliffs, Fosberg 46723. Only seen sterile.

PANDANUS TECTORIUS Park.
Forming thickets and small patches of forest back of cliff tops, Fosberg 46715. Krämer, p. 389.

GRAMINEAE

*ANDROPOGON INTERMEDIUS R. Br.
Local weed in sweet potato field, Fosberg 46675. This is a dominant grass in the grassy savannas of Yap and may well have been introduced from there.

*CHRYSOPOGON ACICULATUS (Retz.) Trin.
Local in edges of sweet potato field, Fosberg 46659. A widespread weed in many Pacific islands.

*DIGITARIA VIOLASCENS Link
Common locally in sweet potato fields, Fosberg 46673. Clumps erect, unusually tall for this species.

*ELEUSINE INDICA (L.) Gaertn.
Common along paths in Lochochoy village, Evans 342; "fathil."

*ERAGROSTIS TENELLA (L.) Beauv. (E. ambilis (L.) W. & A.)
Occasional on cultivated ground in Lochochoy village, Evans 346; "fathil."

ISCHAEMUM DIGITATUM Brongn. ?
Locally dominant in small clearing just inside forest strip on south side of island, Fosberg 46713. Culms erect, to 1 meter tall, from prostrate, superficial rhizomes; seen only sterile, therefore this determination is only very tentative.

*PASPALUM CONJUGATUM Berg.
Weed in cultivated ground, in paths and around dwellings, Fosberg 46657, 46665, Evans 347; "fathil."

PASPALUM DISTICHUM L. (P. vaginatum Sw.)
Dominant locally in open, very rough, eroded coral limestone terrace at top of cliffs on south shore of island, Fosberg 46733.

*PASPALUM SCROBICULATUM L.
Rare in sweet potato fields, Fosberg 46674. This is a very robust form that may best be placed in var. auriculatum (Presl) Merr.

SPOROBOLUS FARINOSUS Hosok.
Forming pure stands on very rough, eroded coral limestone just back of edges of cliffs on terrace on south side of island,

Fosberg 46727. Dense, firm tussocks of fibrous leaf and stem bases, leaves glaucous, seen only sterile. Known otherwise from Guam.

THUAREA INVOLUTA (Forst. f.) R. & S.
Occasional in coconut plantation on plateau, Fosberg 46709. Prostrate, forming loose mats.

*ZOYSIA TENUIFOLIA Trin.
Common, forming dense mats and cushions, in Lochochoy village, Evans 379; "fathil."

CYPERACEAE

FIMBRISTYLIS CYMOSA R. Br.
Common on rough limestone on cliffs and eroded terrace on south side of island, Fosberg 46725.

ARACEAE

*ALOCASIA MACRORRHIZA (L.) Schott
Commonly planted in village and in small clearings, spontaneous in coconut plantation on plateau, Evans 386, Fosberg 46696. Leaves reaching large size in favorable places. This is one of the few places where this aroid is planted for food. Krämer, p. 389, as "grosser Taro."

*COLOCASIA ESCULENTA (L.) Schott
Commonly cultivated in Lochochoy village, Evans 385. Krämer, p. 389, as "Taro."

*CYRTOSPERMA CHAMISSONIS Merr.
Planted in moist taro pit in coconut plantation on plateau, Fosberg 46683. Not seen elsewhere.

*XANTHOSOMA SAGITTIFOLIUM (L.) Schott
Frequently cultivated in Lochochoy village, Evans 387.

PALMAE

*COCOS NUCIFERA L.
Planted abundantly on sand flats back of beaches and on large areas on plateau. Not collected. Krämer, p. 331.

COMMELINACEAE

*COMMELINA sp.
Not seen by us, but reported by Krämer, p. 390.

*RHOEO SPATHACEA (Sw.) Stearn
Common around taro pit in coconut plantation on plateau, Fosberg 46682. Probably persisting from cultivation as an ornamental.

AMARYLLIDACEAE

*CRINUM ASIATICUM L.
Occasional along path at back of beach rampart, Evans 363; "giob." Used for medicine. Krämer, p. 390.

*HYMENOCALLIS LITTORALIS (Jacq.) Salisb.
Planted and spontaneous in village and back of beach, Fosberg 46649, Evans 377; "ropig." Flowers used to make garlands, or "maremar."

*ZEPHYRANTHES ROSEA (Spreng.) Lindl.
Rare along path in Lochochoy village, Evans 375. "Introduced from Japan."

DIOSCOREACEAE

DIOSCOREA BULBIFERA L.
Occasional in coconut plantation on plateau, Fosberg 46689.

*DIOSCOREA ESCULENTA var. FASCICULATA (Roxb.) Pr. & Burk.
Occasional in edges of sweet potato fields and frequent in village, climbing on shrubs, Fosberg 46676, Evans 351; "tal." Tubers eaten. Krämer, p. 389, as "yams."

TACCACEAE

TACCA LEONTOPETALOIDES (L.) O. Ktze.
Common in coconut plantation on plateau, Fosberg 46702. Apparently spontaneous. Krämer, pp. 331, 390, as "Tacca Stärkewurzel."

MUSACEAE

*MUSA SAPIENTUM L.
Common in coconut plantation and village. Not collected. Krämer, p. 332.

ZINGIBERACEAE

CURCUMA spp.
Possibly two species present, a small one, Evans 381, "guchol," said to be used for medicine and to make garlands; another, much larger, to 1 meter or more tall seen but not collected. Both growing in village. Both seen sterile only.

PIPERACEAE

*PIPER BETLE L.
Occasional in Lochochoy village, climbing on large trees, Evans 357; "habui." Chewed with Betel nut.

MORACEAE

*ARTOCARPUS ALTILIS (Park.) Fosb.
Common in coconut plantation and on plateau, Fosberg 46703. The breadfruit. Krämer, pp. 332, 390, as "Brotfrucht-Arten."

FICUS TINCTORIA Forst. f.
Occasional in undergrowth in forest and coconut plantation on plateau, also in village, Fosberg 46717, Evans 382; "gawal." Fruit eaten. Krämer, p. 390.

URTICACEAE

*PILEA MICROPHYLLA L.
Common on stones lining paths in Lochochoy village, Evans 348. "Introduced."

PIPTURUS ARGENTEUS (Forst. f.) Wedd.
Common in dense scrub forest back of cliffs, Yldow, Fosberg 46719, 46720. Krämer, p. 389, as Pipturus.

NYCTAGINACEAE

BOERHAVIA MUTABILIS R. Br. ?
Occasional in sweet potato fields, Fosberg 46664. A very small-leafed form that may belong to this species.

*MIRABILIS JALAPA L.
Occasional in open spaces in Lochochoy village, Evans 380; "gaelun." Used for garlands, "maremar."

PISONIA GRANDIS R. Br.
We did not see this but Krämer, p. 390, reported it as "Strandbaum, Blüten mit 8 Staubgefässen."

AMARANTHACEAE

*ACHYRANTHES ASPERA L.
Common in small clearing dominated by long grass, Fosberg 46711.

AMARANTHUS VIRIDIS L.
Frequent in village, Evans 343; "waluwol."

PORTULACACEAE

PORTULACA SAMOENSIS v. Poelln.

Occasional in sweet potato fields, Fosberg 46661. Widespread weed of open places in the central Pacific islands. ? Krämer, p. 389, as "Fetthenne mit gelben Blüten."

LAURACEAE

CASSYTHA FILIFORMIS L.

Common, parasitic on various hosts, in coconut plantation on plateau, Fosberg 46693. Pantropical. Krämer, p. 390, as Cassytha.

HERNANDIACEAE

HERNANDIA SONORA L.

One tree seen in Lochochoy village, Fosberg 46654. Widespread strand tree.

CAPPARIDACEAE

CAPPARIS CORDIFOLIA Lam.

Occasional, sprawling on low shrubs on beach rampart, Evans 359; "choriuth." Widespread on elevated coral islands in central and western Pacific.

CRATEVA SPECIOSA Volk.

Occasional in Lochochoy village, Evans 374; "yafuch." Used for medicine; fruit eaten. Krämer, p. 389, as Crataeva.

LEGUMINOSAE

*CAESALPINIA PULCHERRIMA (L.) Sw.

Commonly planted in Lochochoy village, Fosberg 46652, Evans 352; "warapig." Flowers used for garlands, "maremar."

*CASSIA OCCIDENTALIS L.

Occasional in sweet potato fields, Fosberg 46677. Pantropical weed.

CASSIA SOPHERA L.

Not seen by us, reported by Krämer, p. 390, but this may be a misidentification of C. occidentalis L.

*DELONIX REGIA (Boj.) Raf. ?

Rare planted tree in Lochochoy village, Evans 372; "warapig." Sterile.

*DERRIS ELLIPTICA (Roxb.) Benth.
Not seen by us, but reported by Krämer, p. 390.

*DESMODIUM TRIFLORUM (L.) DC.
Occasional in sweet potato fields, Fosberg 46678. Widespread tropical weed.

VIGNA MARINA (Burm.) Merr.
Common in sweet potato fields and at top of beach, Fosberg 46660, Evans 361; "holu." Leaves used for medicine. Krämer, p. 390, as *V. lutea*.

OXALIDACEAE

*OXALIS CORNICULATA L.
Occasional in sweet potato fields, Fosberg 46669. Widespread, variable weed; var. *corniculata* probably the one found here.

RUTACEAE

*CITRUS GRANDIS (L.) Osb. ?
Planted around dwellings in Lochochoy village, Fosberg 46650.

*CITRUS SINENSIS Osb.
Planted around dwellings in Lochochoy village, Fosberg 46651.

SURIANACEAE

SURIANA MARITIMA L.
We did not see this, but Krämer, p. 390, reported it as "Strand-Myrthe."

SIMARUBACEAE

SOULAMEA AMARA Lam.
Not seen by us but reported by Krämer, p. 390, as *Soulamea*.

POLYGALACEAE

POLYGALA PANICULATA L.
Common in sweet potato fields, Fosberg 46667. Widespread weed in western Pacific.

EUPHORBIACEAE

*ACALYPHA LANCEOLATA Willd.
Common in open sweet potato fields, Fosberg 46666.

EUPHORBIA PROSTRATA Ait. ?
Frequent along paths and in open spaces in Lochochoy village, Evans 383. Pantropical weed.

*EUPHORBIA CYATHOPHORA Murr.
Rare, along paths in Lochochoy village, Evans 373. "Introduced."

*EUPHORBIA HIRTA L.
In village, coconut plantations and other disturbed places, Fosberg 46701, Evans 366; "habulbul." Pantropical weed. Krämer, p. 389, as E. pilulifera.

EUPHORBIA THYMIFOLIA L. ?
In village, along paths, Evans 388. Pantropical weed.

*MANIHOT ESCULENTA Crantz
Said to be cultivated on the island but not seen by us.

*PHYLLANTHUS AMARUS Schum. & Thonn. (P. niruri Sch. & Th. non L.)
Locally common in cultivated and disturbed ground, Fosberg 46668, 46680, Evans 345; "piapi." Widespread tropical weed.

*PHYLLANTHUS URINARIA L.
In sweet potato fields, Fosberg 46663. Widespread tropical weed.

SAPINDACEAE

ALLOPHYLUS TIMORENSIS Bl.
Rare in dense scrub forest back of cliff, Fosberg 46722. Widespread strand species. Krämer, p. 390, as "Allophyllus Dreiblatt."

TILIACEAE

*CORCHORUS AESTUANS L.
Common in sweet potato fields, Fosberg 46671. Pantropical weed.

*MUNTINGIA CALABURA L.
Rare, in open space beside house in Lochochoy village, Evans 369; "sugar." "Introduced from Ulithi." Fruit eaten.

TRIUMFETTA PROCUMBENS Forst. f.
Top of beach, seen but not collected. Krämer, p. 389, as "Trionfettia procumbens."

MALVACEAE

*HIBISCUS ABELMOSCHUS L.
Uncommon in small opening in coconut plantation on plateau, Fosberg 46714. Only seen sterile. ? Krämer, p. 389, as H. moschatus.

HIBISCUS TILIACEUS L.

Common in coconut plantations and in inner edges of forest zone at top of cliffs, Fosberg 46691. Pantropical. Krämer, p. 390.

*HIBISCUS ROSA-SINENSIS L.

Not seen by us but reported by Krämer, p. 389.

*SIDA MICROPHYLLA Cav.

Occasional in sweet potato fields, Fosberg 46670.

STERCULIACEAE

MELOCHIA COMPACTA Hochr.

Occasional in inner edge of forest zone back of cliffs, and in coconut plantation on plateau, Fosberg 46694, 46707. Krämer, p. 390, as *M. indica*.

GUTTIFERAE

CALOPHYLLUM INOPHYLLUM L.

Occasional in coconut plantations and back of beach, Fosberg 46708. Only seen sterile. Pantropical. Krämer, pp. 324, 389, as *Calophyllum*.

MAMMEA ODORATA (Raf.) Kost.

One tree seen in Lochochoy village, Fosberg 46653. Characteristic plant of elevated limestone situations in Micronesia.

CARICACEAE

*CARICA PAPAYA L.

Spontaneous in coconut plantations on plateau and commonly cultivated in Lochochoy village, Evans 370; "papaya." Fruit eaten. Flowers used for garlands, or "maremar." Krämer, pp. 331, 389, as "Papaya."

LYTHRACEAE

PEMPHIS ACIDULA Forst.

Not seen by us but doubtless present; probably the "gutes schweres Holz" and the "Myrthe" of Krämer, p. 389.

COMBRETACEAE

TERMINALIA CATAPPA L.

Rare in coconut plantation on plateau, Fosberg 46686. Krämer, p. 390. Pantropical lowland tree.

LECYTHIDACEAE

BARRINGTONIA ASIATICA (L.) Kurz

Dominant tree in scrub forest back of tops of cliffs on plateau, also frequent back of beaches, Fosberg 46716, Evans 376; "gol." Used medicinally; wood used for canoe-making. Krämer, p. 390, as "Barringtonie."

MYRTACEAE

*EUGENIA AQUEA L. ?

Occasional, planted in village, Evans 384; "apol garavan." Used medicinally.

EUGENIA JAVANICA Lam.

Occasional in coconut plantations on plateau. Fosberg 46698.

ARALIACEAE

*POLYSCIAS GUILFOYLEI (Cogn. & March.) Bailey

Frequent as hedge along paths in Lochochoy village, Evans 356. "Introduced."

*POLYSCIAS SCUTELLARIA (Burm. f.) Fosb.

Occasional as hedge along paths in Lochochoy village, Evans 355. "Introduced from Japan."

*POLYSCIAS FRUTICOSA (L.) Harms

Planted as hedge in village, Evans 365.

UMBELLIFERAE

CENTELLA ASIATICA (L.) Urb.

Very local in coconut plantation on plateau, Fosberg 46710. Widespread Pacific plant.

GENTIANACEAE

FAGRAEA BERTERIANA Gray ex Benth. ?

Not seen by us, but reported by Krämer, p. 390, as *Fragraea*.

APOCYNACEAE

OCHROSIA OPPOSITIFOLIA (Lam.) Schum.

Occasional in coconut plantation on plateau and in open spaces in Lochochoy village, Evans 378; "mo." Used for medicine.

*PLUMERIA RUBRA L.
Occasional along paths in Lochochoy village, Evans 350; "sour." Flowers used for garlands, "maremar."

CONVOLVULACEAE

*IPOMOEA BATATAS (L.) Lam.
Abundantly cultivated, Fosberg 46662. Probably more than one cultivar present. Krämer, pp. 330, 389.

IPOMOEA LITTORALIS Bl.
Rare in coconut plantation on plateau, Fosberg 46692. Widespread Pacific and probably pantropical species. Only seen sterile on Fais. Krämer, pp. 332, 389.

*OPERCULINA VENTRICOSA (Bert.) Peter ?
Very local at inner edge of forest zone back of cliffs, in coconut plantation, Fosberg 46721. A very coarse, extensive twiner, only seen sterile. It is probably this species rather than O. turpethum, as the stems are not winged. If this identification is correct, this is an addition to the Caroline Islands flora, as the species is known in Micronesia only from the Marianas. ? Krämer, p. 389, as "grosse Winde Marremia convolv."

BORAGINACEAE

HELIOTROPIUM ANOMALUM H. & A.
Very common on open, very rough, eroded coral limestone terrace at top of cliffs on west side of island, Fosberg 46726. A species of wide but peculiar distribution in the Pacific; this is the first record from the Caroline Islands.

TOURNEFORTIA ARGENTEA L. f.
Common at top of beach and on outer edges of forests at top of cliff, Evans 360, Fosberg 46729; "chel." Wood used for canoe-making. Krämer, p. 389, as Tournefortia.

VERBENACEAE

CALLICARPA CANDICANS (Burm. f.) Hochr.
Occasional in coconut plantation on plateau, Fosberg 46687. Widespread western Pacific species; the Micronesian plants often called C. erioclona Schauer, which may be identical or at least very close. ? Krämer, p. 389, as "lila Beeren."

CLERODENDRUM SPECIOSISSIMUM van Geert
Occasional in coconut plantation on plateau, Fosberg 46712. Apparently native in Western Carolines. Krämer, p. 390, as Clerodendron.

PREMNA OBTUSIFOLIA R. Br.
Common generally in interior of plateau and in village, Fosberg 46681, Evans 371; "yar." Used medicinally. Krämer, p. 389, as Premna.

LABIATAE

*OCIMUM SANCTUM L.
Occasionally planted in village. Two forms represented, one low growing and purplish, Fosberg 46648, Evans 368, and a taller greenish form, Evans 367; both called "warong." Commonly planted and highly prized for its odor throughout the Western Pacific. Krämer, p. 390, as "Minze riechend."

SOLANACEAE

*CAPSICUM FRUTESCENS L.
Uncommon around dwellings in Lochochoy, Fosberg 46655. The chili pepper.

*NICOTIANA TABACUM L.
Cultivated in substantial amounts on the island, but not seen or collected on this visit.

*PHYSALIS ANGULATA L.
Locally common in sweet potato fields, Fosberg 46679. Pantropical.

ACANTHACEAE

BLECHUM BROWNEI f. PUBERULUM Leonard
Weed in moist taro pit in coconut plantation on plateau, Fosberg 46684.

RUBIACEAE

GUETTARDA SPECIOSA L.
Common in dense scrub forest back of cliffs and occasional along paths in Lochochoy village, Fosberg 46718, Evans 353; "outh." Flowers used for garlands, or "maremar."

HEDYOTIS ALBIDO-PUNCTATA (Merr.) Fosb.
Generally common on rough, eroded limestone, Fosberg 46728, 46731. Widespread in Western Pacific in strand situations, especially on rough limestone.

*HEDYOTIS CORYMBOSA (L.) Lam.
Occasional in clearings in coconut plantation on plateau, Fosberg 46685. Pantropical weed.

IXORA CASEI Hance
Occasional in village, Fosberg 46658, Evans 354; "hachiu" or "hachio."

MORINDA CITRIFOLIA L.
Common generally in coconut plantations; in inner edge of forest and in village, Fosberg 46706, Evans 358; "lol." Ripe fruit eaten with water and sugar. Krämer, pp. 331, 390, as Morinda.

MUSSAENDA FRONDOSA L.
Occasional in coconut plantation on plateau, Fosberg 46688, 46690. Common from India to Western Carolines. Variable species, often divided into several or many ill-distinguished microspecies. Krämer, p. 389, as Mussaenda.

PSYCHOTRIA ? sp.
Occasional in coconut plantation on plateau, Fosberg 46704. Sterile shrub, probably belonging to this genus. This may be an undescribed species and every effort should be made to re-collect it in a fertile condition.

RANDIA COCHINCHINENSIS (Lour.) Merr.
Common in coconut plantation on plateau, Fosberg 46699. Only seen as a shrub here. A common Indo-Pacific shrub or small tree, reaching as far east as the Southern Marshalls.

CAMPANULACEAE

*HIPPOBROMA LONGIFLORA (L.) G. Don
Frequent on cultivated ground, along paths and around dwellings in Lochochoy village, Fosberg 46656, Evans 349. "Introduced from Palau."

GOODENIACEAE

SCAEVOLA TACCADA (Gaertn.) Roxb.
Common at top of and back of beach, also at outer edge of forest at top of cliffs; less common in coconut plantations, Fosberg 46730, Evans 362; "lath." Stems used medicinally. A widespread Indo-Pacific strand shrub. Krämer, p. 390, as Scaevola.

COMPOSITAE

*AGERATUM CONYZOIDES L.
Not seen by us, but reported by Krämer, p. 390, as "Ageratum lila."

*EMILIA SONCHIFOLIA (L.) DC.
Common in sweet potato fields, Fosberg 46672. Pantropical weed.

*VERNONIA CINEREA (L.) Less. var. PARVIFLORA DC.

Locally common in coconut plantation on plateau and on cultivated ground in Lochochoy village, Fosberg 46700, Evans 344. "Introduced from Yap." Pantropical species.

WEDELIA BIFLORA (L.) DC.

Common on rough, eroded limestone at top of cliffs, Fosberg 46724. Widespread Indo-Pacific strand species. Krämer, p. 389, as Wedelia.

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PLANTS COLLECTED ON ISLANDS IN THE WESTERN INDIAN OCEAN DURING A CRUISE OF THE M.F.R.V. "MANIHINE," SEPT. - OCT. 1967

by M. D. Gwynne and D. Wood

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PLANTS COLLECTED ON ISLANDS IN THE WESTERN INDIAN OCEAN DURING A CRUISE OF THE M.F.R.V. "MANIHINE," SEPT.-OCT. 1967

by M. D. Gwynne [1] and D. Wood [2]

INTRODUCTION

The islands covered by this account lie in the Western Indian Ocean between latitudes 5°S - 10°S and longitudes 46°E - 57°E. They are, in order of visiting, Remire (REM in the following table), Daros (DAR, including the islands of Ressource, Fouquet and St. Joseph), Desroches (DES), Coëtivy (COE), Farquhar (FAR, including Ile du Nord, Ile du Sud & Goëlette), Cosmoledo (COS, including Menai & Grand Ile), Astove (AST) and Assomption (ASS). Aldabra was also visited but was not included on the list. These islands are all "low" islands, the highest point on all being the tops of sand dunes. The geological structure has been detailed by Baker (1963) who classes Remire, Daros, Desroches, Coëtivy and Farquhar as sand cays and Cosmoledo, Astove and Assomption as raised reef-rock islands.

Botanically the islands of the Western Indian Ocean have received mixed coverage. The "high" islands such as Mauritius and the granite islands of the main Seychelles group have attracted attention because of their commercial importance and interesting flora. The raised reef-rock islands have been relatively well visited because of their endemic flora and fauna. This is particularly true of Aldabra--the largest of the "low" islands.

The flora of the sand cays is comparatively little known, the most recent systematic account being by Hemsley (1919). Other references to accounts of the flora of islands covered by the present list are to be found in Blake and Atwood (1942), Peters (1957) and Stoddart (1967).

The following list is by no means a complete account of the flora of any of the islands visited. This is particularly so of Farquhar, Cosmoledo, Astove and Assomption, where a combination of a short stay on the islands and a low proportion of the plants in flower produced a collection comparatively meager in relation to what must be the total flora of these islands.

1/ East African Agriculture and Forestry Research Organisation, Muguga, Kenya.

2/ Royal Botanic Garden, Edinburgh, Scotland.

The arrangement of the angiosperm families in the table follows that of Hutchinson (1926 & 1934). This is the sequence used at the East African Herbarium, Nairobi, where the collection was identified. If a species was not represented in the East African Herbarium it was identified from descriptions alone. Numbers in the table are Gwynne & Wood collecting numbers. Most of these are deposited in the East African Herbarium (EA). "S" signifies a sight record only.

LIST OF PLANTS

	REM	DAR	DES	COE	FAR	COS	AST	ASS
PTERIDOPHYTES								
Psilotum nudum (L.) Beauv.				1109 1153		S		
Acrostichum aureum L.				1088				
Asplenium nidus L.				1085				
Nephrolepis biserrata (Sw.) Schott	890			1085B	1179			
Phymatodes scolopendria (Burm.) Ching				1097 1150				
Pteris tripartita Swartz				1084				
ANGIOSPERMS								
LAURACEAE								
Cassytha filiformis L.	899	943 948 965	S	S	S	S		
HERNANDIACEAE								
Hernandia sonora L.	S	922 954	1041	1165	S			

	REM	DAR	DES	COE	FAR	COS	AST	ASS
TURNERACEAE								
Turnera ulmifolia L.	897	927 950 961 988		1148				
CAPPARIDACEAE								
Capparis cartilaginea Decne							1291B	
Cleome strigosa (Boj.) Oliv.						1251	1303	
Cleome viscosa L.	859			S				
Gynandropsis gynandra (L.) Briq.					1204			
MORINGACEAE								
Moringa oleifera Lam.						1254		
CRASSULACEAE								
Bryophyllum pinnatum (Lam.) Kurz.		1014		1145	S			
AIZOACEAE								
Sesuvium portulacastrum (L.) L.						1266	1318	
PORTULACACEAE								
Portulaca oleracea L.	901			1138	1205	1223	1298	
AMARANTHACEAE								
Achyranthes aspera L.	902	1060		1140	1189	1224	1317	
Alternanthera sessilis R. Br.				1108A				
Amaranthus dubius Mart.	860							

	REM	DAR	DES	COE	FAR	COS	AST	ASS
ZYGOPHYLLACEAE								
Tribulus cistoides L.					1193			
LYTHRACEAE								
Pemphis acidula Forst.	955 980 1058				1080	S	S	S
NYCTAGINACEAE								
Boerhavia coccinea Mill.				1162	1185 1211	1258	1314	1330
Boerhavia diffusa L.	877 886	S						
Mirabilis jalapa L.		944A 1029			1199			
Pisonia grandis R. Br.		931 941 947B 986				1228	1300	
PASSIFLORACEAE								
Passiflora foetida L.							1332	
Passiflora suberosa L.	876	962 968 984 1062	S	S	S	S		
CUCURBITACEAE								
Cucumis melo L.				1108B		1255		
Cucurbita pepo L.					1190			
Mukia maderaspatana (L.) Roem.					1194 1219			

	REM	DAR	DES	COE	FAR	COS	AST	ASS
LECYTHIDACEAE								
Barringtonia asiatica (L.) Kurz		920		1119				
COMBRETACEAE								
Terminalia catappa L.	907		S	1095	S			
RHIZOPHORACEAE								
Bruguiera gymnorrhiza (L.) Lam.						1259		
Rhizophora mucronata Lam.						1261		
GUTTIFERAE								
Calophyllum inophyllum L.	866			1094				
TILIACEAE								
Grewia salicifolia Schinz (vel. sp. aff.)						1257		
Triumfetta procumbens Forst.				1126A				
MALVACEAE								
Abutilon mauritianum (Jacq.) Medic.	870							
Gossypium hirsutum L.		935		1093	1191	1226	1328	
Sida parvifolia DC.	855	972	1035	1166	1210	S	1313	
Sida rhombifolia L.		1027						
Thespesia populnea (L.) Corr.	868							

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Thespesia populneoides (Roxb.) Kostel.						1236	1297	
ERYTHROXYLACEAE								
Erythroxylon acranthum Hemsl.						1233		
EUPHORBIACEAE								
Acalypha claoxyloides Hutch.						1240	1299 1319 1322	
Acalypha indica L.	874							
Euphorbia cyathophora Murr.		1022						
Euphorbia hirta L.	856	1023			1198			
Euphorbia prostrata Ait.	861							
Euphorbia sp.						1230		
Pedilanthus tithymaloides (L.) Poit.	905							
Phyllanthus maderaspatensis L.	881	975 989 1030	1040 1050	1090 1158	1212		1325	
Phyllanthus amarus Schum. & Thonn.	887							
Ricinus communis L.	S	S		1146		S		
CAESALPINIACEAE								
Caesalpinia bonduc (L.) Roxb.	864					1248		
Cassia occidentalis L.	863						S	

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Tamarindus indica L.				1087				
MIMOSACEAE								
Adenanthera pavonina L.		1031						
Leucaena leucocephala (Lam.) de Wit	888	919 1016			1186			
PAPILIONACEAE								
Canavalia cathartica Thouars				1122				
Gliricidia sepium (Jacq.) Steud.				1086				
Sesbania sericea (Willd.) Link		1002						
CASUARINACEAE								
Casuarina equisetifolia L.	891	963 1026	S	S	S	S	S	S
MORACEAE								
Ficus sp.					1188	1241		
URTICACEAE								
Pipturus argenteus Wedd.				1136				
Laportea aestuans (L.) Chew	906	942			S			
CELASTRACEAE								
Maytenus senegalensis (Lam.) Exell							1302	
SALVADORACEAE								
Azima tetracantha Lam.						1243		

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Salvadora angustifolia Turrill						1242 1247		
RHAMNACEAE								
Colubrina asiatica (L.) Brongn.						1256 1262	1308	
Scutia myrtina (Burm. f.) Kurz						1244	1294	
SIMAROUBACEAE								
Suriana maritima L.		937 979	1037	1128	1187	S		
SAPOTACEAE								
Sideroxylon inerme L.							1309	
APOCYNACEAE								
Ochrosia oppositifolia (Lam.) K. Schum.	893	923						
Vinca rosea L.	857	951 1028				S	1327	
ASCLEPIADACEAE								
Pleurostelma cernuum (Decne.) Bullock						1234 1252		
Sarcostemma viminale R. Br.						1239	1293	
Secamone fryeri Hemsl.							1296 1333	
RUBIACEAE								
Guettarda speciosa L.	869	930 944B 964 978	1037			S	1321	

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Morinda citrifolia L.		1020		1126B				
Oldenlandia congesta Balf. f.							1326	
COMPOSITAE								
Bidens pilosa L.	880	956 1005			1192			
Gaillardia sp.					1207 1208			
Launaea intybacea (Jacq.) Beauv.						1253	1316	
Launaea sarmentosa (Willd.) O. Ktze						1229		
Tridax procumbens L.	889	974	S	1113 1121A				
Vernonia cinerea (L.) Less.		970	1047	1147	1196			
Vernonia aldabrensis Hemsl.							1292	
PLUMBAGINACEAE								
Plumbago aphylla Boiss.						1227	1290	1334
LOBELIACEAE								
Isotoma longiflora (L.) Presl				1146A				
GOODENIACEAE								
Scaevola taccada (Gaertn.) Roxb.	865	977	S	1141	S	S		
BORAGINACEAE								
Cordia subcordata Lam.	867 904	921 947A				1301		

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Tournefortia argentea L. f.	903	1019	S	S	S			
SOLANACEAE								
Datura metel L.	882							
Solanum nigrum L.	875	1018						
CONVOLVULACEAE								
Evolvulus alsinoides (L.) L.						1231	1331	
Ipomoea pes-caprae (L.) R. Br.	894		S			S		
Ipomoea tuba (Schlecht.) Don		929 932	1042	1091 1159	1209 1218	S	1307	
SCROPHULARIACEAE								
Striga asiatica (L.) O. Ktze		939 969	S	1121B 1142	S			
ACANTHACEAE								
Asystasia bojeriana Nees		1021					1315 1324	
Hypoestes ?aldabrensis Bak.						1225 1264		1329
VERBENACEAE								
Avicennia marina (Forsk.) Vierh.						1260		
Phyla nodiflora (L.) Greene	878	1003	S	1092	S			
Premna obtusifolia R. Br.						1250		
Stachytarpheta jamaicensis L.	862	S	S	1157				

	REM	DAR	DES	COE	FAR	COS	AST	ASS
HYDROCHARITACEAE								
Thalassia hemprichii (Ehrenb.) Aschers.		1056						
ZANNICHELLIACEAE								
Cymodocea ciliata Aschers.	854 898	940 1057	1031A					
Cymodocea sp.					1216			
Halodule uninervis (Forsk.) Aschers.				1130				
Syringodium isoetifolium (Aschers.) Dandy		1007						
COMMELINACEAE								
Commelina ?diffusa Burm. f.	896							
LILIACEAE								
Asparagus sp.						1265		
Lomatophyllum borbonicum Willd.							1295	S
ARACEAE								
Alocasia macrorrhiza (L.) Schott				1089				
Colocasia esculenta (L.) Schott				1152				
AMARYLLIDACEAE								
Crinum angustum Roxb.		957	S	S	S			
AGAVACEAE								
Agave sp.						S		
Furcraea sp.				1085A				

	REM	DAR	DES	COE	FAR	COS	AST	ASS
PALMAE								
Cocos nucifera L.	S	S	S	S	S	S	S	S
PANDANACEAE								
Pandanus utilis Bory				1096				
ORCHIDACEAE								
Vanilla planifolia Andr.		945		S				
CYPERACEAE								
Cyperus ?rotundus L.				1110				
Fimbristylis dichotoma (L.) Vahl				1098 1111 1114 1115 1117 1151				
Fimbrystylis cymosa R. Br.	873	924 958 959 983 1004 1008 1009 1010	1032	1127 1135 1155	1181 1213			
Kyllinga cartilaginea K. Schum.				1134 1156				
Kyllinga erecta Schum.				1107A				
Kyllinga melanosperma Nees	892							
Kyllinga polyphylla Kunth	879			1112				

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Mariscus dubius (Rottb.) Hutch.	885 900	971 1013	1036 1048	1154				
Mariscus ligularis (L.) Hutch.	895	960		1144 1168	1183	S		
Pycreus polystachyus (Rottb.) Beauv.				1116				
GRAMINEAE								
Cenchrus echinatus L.		936			1201			
Cenchrus mitis Anders.	872							
Chloris sp.						1237		
Cynodon sp.			1052					
Dactyloctenium aegyptium (L.) Beauv.	884	934 966 987 1059	1039	1131 1143 1160	S	1263	1291A 1320	
Digitaria horizontalis Willd.		946 1025	1034			1238		
Digitaria timorensis (Kunth) Balansa				1124 1133 1139 1161	1202		1323	
Eleusine indica (L.) Gaertn.		925B 1024	1045		1200 1206			
Enteropogon sp.			1044					
Eragrostis ciliaris (L.) R. Br.		967						

	REM	DAR	DES	COE	FAR	COS	AST	ASS
Eragrostis tenella (L.) Roem. & Schult.			1033	1137 1167				
Eragrostis tenella (L.) Roem. & Schult. var. _insularis_ Hubb.	858 883	925A 928 981	1043	1132 1164	S	S		
Lepturus repens (G. Forst.) R. Br.		926 982		1123	S			
Lepturus sp.						1249		
Panicum maximum Jacq.					1203	1235		
Paspalum distichum L.					1182			
Pennisetum polystachium (L.) Schult.					1184			
Saccharum officinarum L.	908							
Sclerodactylon macrostachyum (Benth.) Camus								1335
Sporobolus virginicus (L.) Kunth							1310	
Stenotaphrum dimidiatum (L.) Brongn.			1051	1118 1163				
Stenotaphrum micranthum (Desv.) Hubb.	871	973 985 1061			1197			

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NO. 135

ISLAND NEWS AND COMMENT

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August 15 1969

ISLAND NEWS AND COMMENT

We continue to invite our readers to send us news items and original observations, as well as publications, on islands. It would help speed up the editing process if your news items were written out in a form suitable for publication, without rewriting. We are, of course, always glad to get letters telling us of plans for field work and other island or reef projects, and will continue to publish what we can extract from them as news. We are sure, however, that you would be much better satisfied if you included, for news purposes, a paragraph for us to use in Island News and Comment.

NEWS

CONSERVATION IN THE BRITISH INDIAN OCEAN TERRITORY: Since the publication of *Atoll Research Bulletin* 118 there have been important developments in the conservation legislation of the British Indian Ocean Territory, which includes Aldabra, Farquhar and Desroches in the western Indian Ocean and the atolls of the Chagos Archipelago in the center. The legislation previously in force was largely that of the Seychelles for the western islands and of Mauritius for the Chagos Archipelago, the territories to which the islands had formerly been attached (*Bulletin* 118, pp. 44-50).

By Ordinance No. 2 of 1968, the Commissioner of BIOT took powers to make regulations for the protection and preservation of wild life. The Ordinance was clearly influenced by earlier bird protection legislation, but it included not only prohibitions on interference with animals or their eggs (*sic*) but also "any change or alteration" in an animal's environment. The first set of regulations under this Ordinance (S.I. No. 11 of 1968) prohibited the taking of green turtle throughout BIOT, and the possession or sale of any turtle products, as from 13 August 1968. Parallel legislation enacted in the Colony of Seychelles means that the green turtle is now protected, at least for a period of years, on all British-controlled islands in the western and central Indian Ocean, including BIOT, the Amirantes, the Seychelles and the Chagos. All green turtle in captivity were set free in BIOT following the publication of these regulations, the intention of which is clearly to attempt to halt the catastrophic decline in breeding numbers before it is too late. Further regulations (S.I. No. 12 of 1968) prohibited the exportation from BIOT of any giant land tortoises without an export permit signed by the Administrator of the Territory, specifying the numbers allowed to be exported. At present up to 50 giant land tortoises per annum are allowed to be exported under license from Aldabra. Both the regulations protecting the green turtle and those controlling the export of tortoises carry penalties of a fine of one thousand rupees (£75 or $180) and one year's imprisonment for their contravention.

REEF STUDIES IN THE SEYCHELLES: The tragic death by drowning on the reefs of Mahé, Seychelles, of Professor J. H. Taylor, F.R.S., in January 1968 is a considerable blow to British reef work in the western Indian Ocean. Professor Taylor, head of the Department of Geology, King's College, London, had published on general problems of diagenesis, but his main contribution to reef studies was his direction of the work of a group of graduate students in work on the reefs of the Seychelles. Of this group, John Taylor, now of the Department of Palaeontology, British Museum (Natural History), has completed a Ph.D. thesis on "Coral reef and associated marine organic communities around Mahé, Seychelles" at the University of London, much of which has been published under the title "Coral reef and associated invertebrate communities (mainly molluscan) around Mahé, Seychelles" in the Philosophical Transactions of the Royal Society, Series B, 254, 129-206. M. S. Lewis, of the Department of Geology, University of Glasgow, has also published a paper on "The morphology of the fringing coral reefs along the east coast of Mahé, Seychelles," Journal of Geology, 76(2), 1968, 140-153. Other papers are in preparation by these and other members of the group. It is hoped that the impetus given to Seychelles reef studies by Professor Taylor will not be lost following his death.

HERON ISLAND RESEARCH STATION: The first issues have been received of a series of publications from the Great Barrier Reef Committee Heron Island Research Station in the general series University of Queensland Papers (University of Queensland Press, St. Lucia, Queensland). Vol. 1, No. 1, by A. B. Cribb, covers "The Algae of Heron Island, Great Barrier Reef, Australia"; Vol. 1, No. 2, by Dale Straughan, "Some Serpulidae (Annelida: Polycheata) from Heron Island, Queensland"; and Vol. 1, No. 3, by W. Stephenson, "The intertidal acorn barnacle *Tetraclita vitiata* Darwin at Heron Island." This series consists of original papers, and is additional to the Great Barrier Reef Committee Heron Island Research Station numbered Reprint Series, of which the most recent (No. 3) is a general article by O. A. Jones and R. Endean on "The Great Barrier Reefs," from Science Journal, November 1967.

EXPEDITION TO PORT SOUDAN, RED SEA: In August and September 1968 a party from Cambridge and Oxford Universities went to Port Sudan, on the western Red Sea coast. The party was lead by Dr. C. H. Roads and consisted of two zoologists, A. C. Campbell (Oxford) and D. J. Teidman (Cambridge); a botanist, J. Gore (Cambridge); and a mathematician, I. M. McCallion (Cambridge). All members of the party were divers, and the aim of the expedition was to investigate the spiny coral-eating starfish *Acanthaster planci* L. in the central Red Sea. This spectacular animal is usually pale green in color, growing up to 50 cm overall diameter, with about sixteen arms and heavily protected by spines.

Acanthaster has been in the news lately because of its sharp population increase on parts of the Queensland Great Barrier Reef where it now occurs in such densities that in some areas very nearly all the coral has been killed in two or three years. This sort of predation of hermatypic corals might lead to the breakdown and loss of whole coral reefs. Lack of information about *Acanthaster* makes control of such populations difficult. It was hoped to find out what *Acanthaster* did in

the more typical situation in the Red Sea, where reported population densities were much lower. Previous work in this area by Goreau in the Dahlak Archipelago indicated that here Acanthaster is nocturnal and territorial in its behavior, returning to a "home" in the reef where it spends the day. By contrast in plague areas in Australia the starfish is evident on the reef by day: this may be abnormal behavior brought about by the high population densities. Goreau observed Acanthaster to feed on scleractinian corals of 7 different species. This it does by everting its stomach over the colony and digesting the coral's tissues outside the body. It then absorbs the products of digestion and leaves behind only the coral skeleton.

The Sudanese coast has a continuous fringing reef, and offshore reefs form a discontinuous barrier reef. A selection of areas in both types of reefs was visited up to 80 km from Port Sudan in an attempt to cover several different habitats: in some of them no Acanthaster were found. A total of only seven starfish was recorded, the maximum density being two on a reef about 100 m by 10-20 m. This suggests that the starfish is normally uncommon. Except for two on a reef in the Suakin Archipelago, about 70 km south of Port Sudan, Acanthaster was nocturnal, sheltering in a crevice or under a coral growth during the day and generally at about 2 or 3 m depth. However, they showed little obvious territorial behavior or evidence of a home, often disappearing after a nocturnal excursion.

The small number of Acanthaster found and their non-territorial behavior made observations difficult. Once an animal was observed throughout the night and seen to eat a piece of Acropora. Other evidence of feeding was obtained from the characteristic patches of predated coral near an Acanthaster. These included Acropora, Pocillopora, Seriatopora, Goniastrea, and Porites. This agrees with Goreau's observations and Acanthaster does appear to feed mainly, if not exclusively, on hermatypic scleractinian corals. Little is known of the amounts eaten, but in the Red Sea these seemed insignificant compared with the total reef, and little damage to the reef structure was apparent. It is possible that the long-term effects of such low-pressure predation could slow down reef formation. It is hoped that further information may be obtained from a following-up main expedition to the Port Sudan region in 1969.

ACANTHASTER IN MICRONESIA: The crown-of-thorns starfish has undergone a population explosion on Guam, and has been exerting a catastrophic effect on the coral reefs there. They have also appeared on Rota and Saipan, according to information from Lu Eldredge. Richard H. Chesher, of the University of Guam, has been investigating the causes and ecology of this outbreak. We hope to have a preliminary account of it from him in a future issue of Atoll Research Bulletin.

ACANTHASTER ON THE GREAT BARRIER REEF: Cards nos. 532 and 535 from the Smithsonian Institution Center for Short-Lived Phenomena call attention to the population explosion of this starfish on the Great Barrier Reef (see above), with a brief report on it from Bob Endean, of the Zoology Department, University of Queensland, that emphasizes the seriousness of the problem. Our only comment is that we sincerely hope this is really a short-lived phenomenon.

BAHAMAS: Dr. Garrett C. Clough has sent us an advance copy of an article to appear in Oryx announcing his rediscovery of one of the rarest and most threatened of small mammals. He introduces his report as follows: "A relic population of the Bahaman hutia, an obscure rodent, has been rediscovered and many new details of its ecology and its habits have been learned. This mammal, Geocapromys ingrahami, had been listed as extinct in some recent books on mammals. Even the few people who were aware of its continued existence knew almost nothing about its biology and numbers. On the tiny island of East Plana Cay, Bahamas, I have found a thriving population living in an interesting ecological situation. At the University of Rhode Island a small colony of captive animals is now breeding successfully."

PALAU CONSERVATION MEETING: Under the auspices of the Terrestrial Conservation Section of the International Biological Programme, a meeting to consider island conservation problems and the possibility of protecting a number of uninhabited islands by international agreement was convened in Koror, Palau Islands, and in Guam, November 18-26, 1968. The Trust Territory Entomology Laboratory on Koror and the Biology Department, University of Guam, were hosts. A number of internationally prominent conservationists and experts on island ecology, as well as many interested local people and representatives of the Trust Territory took part. The meeting was engineered by Mr. Max Nicholson, convenor of the IBP/CT Section, and jointly sponsored by the IBP and the Pacific Science Association. Many general and local conservation problems were aired, including the threats of phosphate mining in the southern Palau lagoon and of strip-mining of the southern half of Guam. It is hoped that these threats of catastrophe can be averted by pressure of public opinion, so as to keep these islands in a habitable and economically viable condition for the future, rather than sacrificing them for short-term economic gain. The results of the meeting will appear in forthcoming issues of Micronesica.

CORALS AND CORAL REEFS SYMPOSIUM: The international scope of interest in coral reefs and their biota was very well demonstrated at the symposium on Corals and Coral Reefs, held at the Central Marine Fisheries Institute at Mandapam Camp, Madras State, India, January 12-16, 1969 (see ARB 126, pp. 8-9). This meeting was sponsored by the Marine Biological Association of India, under the leadership of Dr. S. Jones, with Dr. C. S. Gopinadha Pillai as convenor.

Dr. David Stoddart, of Cambridge University, organized the program, but came into the picture too late to exercise any selection of topics. Therefore, in spite of an attempt to bring related talks together, there was a certain lack of scientific focus.

Outstanding was the breadth of material covered and the wide geographical representation, both in reefs reported on and in the countries represented by speakers. In addition to a large representation from the host country, India, the United States, France, Germany, Australia, Brazil, Indonesia, Singapore and Great Britain were represented, as well as FAO with two representatives from the Cochin Marine Station. Geographic areas reported on included South Indian reefs,

Madagascar, the Red Sea, Aldabra, the Maldive and Laccadive Atolls, Andamans, Bermuda, and the Tuamotu Archipelago.

Productivity and other ecological processes, faunistic studies, the functioning of zooxanthellae, the roles of different animal groups in reef ecology, and observations on reef geomorphology were important subjects in the program.

Field trips were enjoyed to reefs and small islands in the Gulf of Mannar and to Rameswaram Island, beyond Mandapam. The Rameswaram visit, in addition to providing an opportunity to study reefs, gave a quick look at some interesting religious ceremonies and an opportunity to see the important temple for which this island is noted. The graciousness and hospitality of our Indian hosts were outstanding, and the entertainment provided each evening brought relaxation from the concentration of the meetings.

The papers presented are to be published by the Marine Biological Association of India.

INDIAN OCEAN SYMPOSIUM: The Marine Biological Association of India announces that its next symposium will be held at Cochin, India, January 12-13, 1971, on the subject: The Indian Ocean and Adjacent Seas--their Origin, Science, and Resources. Inquiries and correspondence relating to the symposium may be addressed to: The Convener, Symposium on Indian Ocean.... Marine Biological Association of India, Marine Fisheries P. O., Madras State, India. The deadline for submission of abstracts is July 15, 1970, and for manuscripts November 15, 1970.

BARBADOS CLIMATOLOGY: McGill University Department of Geography has established a program of climate studies on Barbados, West Indies, starting in 1968. Details of this are given by B. J. Garnier in the Bulletin of the American Meteorological Society, 49:636-639, 1968.

MICRONESIAN ANTHROPOLOGY: Beginning in October 1966, the Department of Anthropology, University of Hawaii, has issued a duplicated bulletin series entitled "Micronesian Program" containing items of interest to anthropologists concerned with Micronesia. Since that time five numbers have appeared, the last one in April 1969. These bulletins are a mine of current and bibliographic information, and may be secured by writing to the editor, Professor Leonard Mason, Department of Anthropology, University of Hawaii, Honolulu, Hawaii, 96822, U.S.A. Of special interest are two items, one in Bulletin 4, a recapitulation and bibliography entitled "Anthropological research in Micronesia (1954-1968)" by Leonard Mason, and, the other, in Bulletin 5, the "Initial Report of the Political Status Commission of the Congress of Micronesia," which makes comprehensive recommendations for the future of the present Trust Territory of the Pacific Islands. It suggests the status of "a 'free associated state,' internally self-governing, with Micronesians in control of all its branches, including the executive, and prepared to negotiate entry into free association with the United States." Presumably this means that the United States is to continue financing the

services that no unit with the small population and geographical peculiarities of Micronesia could possibly sustain. This could continue to be as expensive as it is at present, if the Micronesians expect all the dubious "benefits" of modern technological civilization.

Appended to the report are various editorial and private opinions expressed concerning the work of the Status Commission, some of them by Micronesians who would prefer complete independence. One of these, a Palauan student in Hawaii, Francisco Uludong, made a telling point on the matter of financial dependence when he said to an American Association of University Women audience, "Most of the American money now goes to maintain the American bureaucracy there. Very little of the funds are used for the direct benefit of the Micronesians."

Whatever the merit of such a statement, a careful study of the Status Commission's report and associated comments is warranted by anyone interested in assessing the success or failure of 23 years of United States administration of Micronesia.

MAN IN THE PACIFIC: We are really well supplied with current news letters for Pacific Anthropologists. We have just received no. 8 of Man in the Pacific, published by the Pacific Scientific Information Center, B. P. Bishop Museum, Honolulu. It really overlaps very little with the one described above. Particularly valuable is a list of address changes of those interested in Pacific anthropology.

NEW HIGH COMMISSIONER FOR MICRONESIA: President Nixon, through Interior Secretary Hickel, accepted High Commissioner Norwood's courtesy resignation, making it effective February 28. There followed a series of acting High Commissioners, as provided by statute, until, on April 24, the President announced the appointment, subject to Senate confirmation, of Mr. Edward E. Johnson, Hawaii State Republican Party Chairman, as the new High Commissioner. Conservationists are concerned about his attitude as exemplified by his reply to a request for Trust Territory endorsement of the United States-Japan migratory bird treaty, namely that there are too many problems about people in the Trust Territory to bother about birds. A party headed by Secretary Hickel has just completed a brief study visit to Micronesia. The newspaper pronouncements on the outcome of this sounded much like the standard promises of a positive attitude, great interest, etc., etc. We will try to get a more authentic summary of the results of this mission for a future issue, if there seem to be any substantive results.

ALDABRA: On March 13-14, 1969 the Royal Society held a meeting in London and brought together the participants in the various phases of its continuing Aldabra Expedition to compare notes and sum up their results to date. It gave the members of the different phases a chance to meet each other and exchange observations and discuss problems. Various interested organizations were invited to send observers.

The most exciting thing was the announcement by the Royal Society that a Parliamentary grant-in-aid has been secured for the construction of a small permanent research station on the island. There are strong

hopes that the British Indian Ocean Territory will designate the island officially as a nature reserve.

The reports presented at the meeting will be published as a volume of the Philosophical Transactions of the Royal Society. Most of the papers were really progress reports, as the results are by no means all worked up as yet.

We hope, in the next issue, to have a more comprehensive report on the status of research on the island, of the construction and staffing of the station, and a complete list of the phases of the expedition and of its personnel.

OCEANOGRAPHY AND LIMNOLOGY QUARTERLY NEWSLETTER: The Smithsonian Institution's Office of Oceanography's newsletter contains many items that may be of interest to our readers. Requests for this publication may be addressed to the Office of Oceanography, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

NAMOLUK ATOLL, CAROLINE ISLANDS: Mr. Keith "Mac" Marshall, of the Department of Anthropology, University of Washington, Seattle, Washington 98105, U.S.A., and his wife, plan to conduct field work on Namoluk, October 1969-June 1970 and October 1970-April 1971. In addition to his anthropological work and Mrs. Marshall's interest in comparative neurological physiology, Mac has a long-standing interest in ornithology and marine biology, and expects to make observations in these fields, as well as collections of plants. They hope to gather material on native classification systems, as of fishes. They asked us to indicate their willingness to collect material and data for other workers interested in ecological and other problems on Pacific atolls. Naturally they would need to be furnished with specific instructions and any special materials or equipment appropriate for such collections.

ARNO ATOLL, MARSHALL ISLANDS: Mr. Ross Kiester, graduate student at Harvard's Museum of Comparative Zoology, writes that he plans to spend two years on Arno, carrying out experimental ecology and competition studies on the skink, Emoia. He expects, as a background to these studies, to do extensive ecological surveys of the islands on which he will work.

Also planning research on Arno, June 1969-December 1970, is Michael A. Rynkiewich, of the Anthropology Department, University of Minnesota, Minneapolis, Minnesota 55455. His project is sponsored by the National Institutes of General Medical Sciences. He writes: "Ethnographic research will be conducted on Arno Atoll, Marshall Islands, Trust Territory of the Pacific (Micronesia). The atoll has approximately 1400 people. The basic problem has been outlined by Ward Goodenough as 'A Problem in Malayo-Polynesian Social Organization.' Given a limited amount of land, unilineal descent groups with control over land use, and differential growth among lineages, inequalities in the man-land ratio develop. There are alternative solutions to this problem, e.g., adoption, usufruct rights, gift-giving outside the

lineage, non-unilineal descent groups. The problem is to examine the mix of alternatives in use on this particular atoll. The second and closely related problem is concerned with the changing bases for statuses of political authority. Traditionally, these were based on seniority of rank within kin groupings and control over land. In recent years, western democratic institutions have been introduced. The articulation between the old and new systems will be investigated."

VISITORS FROM TARAWA: Dr. Peter D. Matthews, of the Medical Department, Bikenibeu, Tarawa, Gilbert and Ellice Islands Colony, and Mrs. Jean Matthews, plan a stop in Washington and a visit to the Editors at the Smithsonian on their way back from home leave to Tarawa at the end of June. They were respectively Chairman, and Catering and Welfare Officer, for the South Pacific Commission 1957 seminar on Health Problems of Coral Atoll Populations (see ARB 119, p. 2). Theirs were most important contributions to a very successful meeting, and we are looking forward to their visit. A lecture on the Gilbert Islands and the Gilbertese by Dr. Matthews will be arranged at the Museum of Natural History.

CONTINUED FRENCH NUCLEAR TESTING IN THE TUAMOTUS: Mr. A. G. Mercer, of the Department of Jurisprudence and Constitutional Law at Victoria University, Wellington, New Zealand, has recently reviewed the legal issues surrounding testing on remote islands in oceanic areas ("International law and French nuclear weapons tests," Pacific Viewpoint, 9, 1968, 51-68). He concludes that although "testing on the high seas is a reprehensible practice and France in pursuing her policy toward nuclear statehood has been subjected to withering criticism from many quarters," nevertheless "whether or not it is heartless, immoral or impolitic to conduct the nuclear weapons tests, the anticipated critical health hazard has not materialised nor has the series violated any established rule of international law."

We have been informed that the planned tests at Fangataufa have been suspended, at least for the present.

ISLAND FILMS: We have recently seen three superb films on island birds and other animals. One, entitled "Albatross" was made by Harvey I. Fisher, and portrays the life cycle of the Laysan albatross on Midway Island. The second is "Galapagos--Wild Eden," photographed with all of his customary artistic gift by Roger Tory Peterson. This film was started on the University of California Expedition to the Galapagos, when one of your editors enjoyed the company of Dr. Peterson, and continued the following year when Peterson was a camera man for the Canadian Broadcasting Company's Galapagos Expedition. The result is as vivid an account of the natural history of these fascinating islands as could be crowded into a single evening's entertainment.

Another film on the Galapagos, different, but equally rewarding from the biologist's viewpoint, is "Voyage to the Enchanted Isles" photographed by Alan and Joan Root, arranged for the Charles Darwin Foundation by Aubrey Buxton with very effective narration by H. R. H. Prince Philip. Emphasis is on the remarkable behavior of some of the vertebrate animals, but the vegetation is well shown as

a background to these. The urgency of the issue of conservation in these islands is obvious to anyone who sees this film with an appreciative eye. It features the Charles Darwin Research Station at Academy Bay, center for active and continuing research on the biology of the Galapagos.

Of immense interest to reef ecologists is the film entitled "The Coral Gardens of Shadwan," made by Helmut and Günther Fleissner, of the Zoological Institute of the University of Frankfurt, Germany. This film was made on coral reefs in the Red Sea and not only shows beautiful reefs, but details of ecological processes and relationships, even including zooxanthellae in the cells of the corals. We hope to have an article on this film and the details of how it was made from Mr. Günther Fleissner, with whom we had the privilege of a visit.

ORIGINAL OBSERVATIONS

TOXOPLASMOSIS ON CAROLINE ATOLLS

by G. D. Wallace
Pacific Research Section, NIAID, P.O. Box 1680,
Honolulu, Hawaii 96806

The epidemiology of toxoplasmosis was investigated on three remote and ecologically simple atolls in the western Pacific. The atolls, Eauripik, Ifalik, and Woleai, are located within 80 miles of each other but travel between them and contact with the outside world is infrequent. The Micronesian residents share the same culture, types of food, and similar environment in general. The prevalence of human infection, as measured by the presence of dye-test antibodies, was high on Ifalik, moderate on Woleai, and nearly absent on Eauripik. On Ifalik and Woleai, there was also serologic evidence of infection in rats, the only wild mammal present, and in the domestic animals, including cats, dogs, and pigs. On Eauripik, however, rats and cats had not become established and the dogs and pigs were serologically negative, except for one dog that had been imported from Woleai. Cats or rats appeared to be the most likely reservoir of _Toxoplasma_ in the atolls. The consumption of raw meat did not appear to be an important source of human infection. (Abstract of a detailed account to appear in an early number of the American Journal of Epidemiology.)

OBSERVATIONS ON THE GREEN TURTLE IN THE MARSHALL ISLANDS

by F. R. Fosberg

Several workers interested in the breeding habits of the green turtle (_Chelone mydas_ (L.)) have suggested that I publish certain observations made in the course of field work in the Marshall Islands

in 1951 and 1952. Turtles were observed to come ashore on Jemo Island during a visit to this island December 18-22, 1951 and on Bikar Atoll during a visit from August 6-12, 1952. Since my observations do not agree in every particular with those of others made in different parts of the world, it seems worthwhile to place them on record in detail.

Jemo is a tiny islet on a small segment of reef, with no lagoon, nor even a pond, located at 10°08' N, 169°32' E, in the northern Marshall Islands, between Likiep and Ailuk atolls. The islet is flat, partly covered by a coconut plantation, with thick forest around part of the periphery and scrub around the rest. Part of the shore is coral sand beach, part beachrock, and part a rough erosion ramp. Back of the shore the ground is largely coral sand.

Shortly after our landing I walked around the beach and counted 44 turtle tracks, indicating that in the past several days 22 turtles had crossed the beach from the sea to the sandy ground at the edge of the vegetation, then recrossed it back to the sea. Usually, at the edge of, or just inside, the vegetation, was a shallow pit about a meter across, with a low pile of sand at one side, thrown out of it. I assumed that the clutch of eggs would be buried in the bottom of the pit, and dug in the bottom of a number of the freshest of them. In each case undisturbed roots were found a little below the bottom. In one case I finally located the eggs, 106 of them, in the bottom of a smaller hole located under the broad pile of sand that was thrown out of the larger pit. The hole had been about 60 cm deep and 30 cm across, straight sided, with sand packed back in it on top of the eggs. The eggs were spherical, about the size and appearance of ping-pong balls, white, with a smooth, dull surface and a translucent spot on one side, where the yolk rested. The shells were only slightly calcified, denting on contact with other eggs or with fingers. The whites were completely non-viscous, clear, and did not coagulate on cooking. The yolks were yellow and soft, and when cooked scrambled, they resembled a cheese omelette or an overcooked welsh rabbit, in both taste and consistency.

At 2 a.m. on the 19th I went out and scouted the beach. The moon was full and the tide low. There were only 2 new tracks, and the turtle that made them was found, heading as rapidly as she could scramble back toward the sea. I turned her over to be photographed in the morning. She struggled for a while, then calmed down, emitting a sighing "ah'h" sound, with tears running from her eyes. Next morning she was lying quietly, but struggled violently when disturbed. After she was measured and photographed she was released and lost no time in reaching deep water. She was mottled dark olive-drab above, yellowish below, measured 75 cm across and 120 cm long, from tip of tail to tip of beak with head drawn in, was quite heavy to turn over, but was not weighed. The mouth was a hard triangular beak with sharp jagged edges. She made no attempt to bite. Her front flippers were long and broadly sword-shaped, the hind ones short and broadly spatulate, the tail short and triangular.

Bikar Atoll is a small atoll, with three principal islets and a small sand bank, on a reef around a lagoon, lying at 12°15' N, 170°05' E,

the next to the northernmost of the Marshall Group. Bikar Islet, the largest of the three, is of sand, except for areas in the interior where this has been cemented into phosphate rock. On the western and southern coasts are sand flats with rather open vegetation much frequented by turtles as nesting sites. An outstanding feature of these parts, especially on the south coast, is the way the sand has been churned up by turtles digging holes in it. On the afternoon of August 6 I counted 596 tracks. That night 6 more turtles came ashore, of which 3 were seen by the party. One was measured, being 70 cm across and 135 cm long. She was strong enough to move on land with a small man sitting on its back. When caught she shed tears. When released she headed back to sea, climbing over very rough pitted rock remnants with some difficulty, but successfully. A few turtles came ashore on each of the following five nights, on August 10 about 15. On August 11 three were seen, but probably more came ashore. One night one blundered through our camp, creating much havoc. One that was spotted coming out of the water was frightened by the light and turned back. Two more turtles were measured, one being 80 cm wide and 122.5 cm long, the other 70 cm wide and 115 cm long. Colors and patterns on shells were most varied.

I watched one come ashore at 8:10 p.m., August 11, before the moon rose. She walked about 50 m inland, poked her front end into a large _Scaevola_ bush, stopped and began to scratch with her hind feet, gradually excavating a hole less than 30 cm across and as deep as the short hind flippers could reach, using a peculiar back-hand scooping motion with alternate feet, each time, while digging with one foot, flipping away the sand that was brought up by the other foot previously. This appeared to be a very inefficient method of digging. When the hole was finished the rear end of the turtle projected over the hole and the tail pointed downward. Eggs were expelled 1-2 or even 3-4 at a time, dropping into the hole. This turtle laid 92 eggs, taking 11 minutes for the actual laying process. Then she filled the hole very carefully with sand, which she patted and pressed down in a mound over the eggs. Gradually she spread this mound out and covered it with dead leaves, then dug a pit to one side and threw the dirt over the hole where the eggs were laid, making a low broad mound over it, so that one would scarcely guess where the eggs were laid. The whole process took over three hours.

Newly laid eggs were seen from 3 different individuals, varying somewhat in size from turtle to turtle. In the clutch of 92 mentioned above was one tiny egg, the size of a marble.

The sand flats, outside of and especially in the open _Tournefortia_ belt around the _Pisonia_ forest that covers most of the islet, were thickly spotted with the shallow pits, 60 cm to 1 m across, each with a low mound at one side. Two of these mounds were observed to have small holes in them, with numbers of small flies buzzing about them, and, in one case, hermit crabs in the holes. These holes may have been made by the hermit crabs, but were more probably made by young turtles emerging. One hole had a broken shell in it.

On the night of August 6 a few black baby turtles were seen hurrying toward the sea. They were being attacked by large red hermit crabs (_Coenobita perlata_) and by rats (_Rattus exulans_). The hermit

crabs bit through the carapace, the rats through the plastron. On August 10 and 11, at about 8 p.m., batches of young turtles hatched out and came running through camp, on their way to the sea. They followed lights.

Almost all of the female turtles that visited Bikar Atoll, well over 300 in the 7 nights, August 5-12, came ashore on Bikar Islet. One set of tracks and a pit were noted on Jaboero Islet, a few on the south part of Almeni Islet, but none on Jaliklik Islet, which is rocky and has no loose sand.

The location of the hole containing the eggs beside the pit excavated by the turtle is in marked contrast with the situation in Malaya and Sarawak, reported by Hendrickson (personal communication), where the hole with the eggs is some distance from the pit.

In 1958 Bikar Atoll and Pokak (Taongi) Atoll, which lies to the north of it, were set aside as preserved natural areas by administrative decree by the then District Administrator, Mr. Maynard Neas. It is hoped that this protection may be strengthened, as clearly Bikar is the principal turtle nesting area in the Marshalls and should be kept as a stocking area for the rest of the archipelago.

PUBLICATIONS

Moreau, R. E., The bird faunas of Africa and its islands. 1-424, Academic Press, London and New York, 1966. $18.00. This is a superb book. Its interest is far broader than its title suggests, and it will hold an audience far wider than the ornithological fraternity. The first three chapters present an excellent, if brief, picture of the geography and ecology of Africa, not just an areal sketch, but soundly based in the time dimension. This makes it possible to consider the entire range of avian biogeography in a convincing ecological context. The fact comes through very clearly that one cannot understand the present distribution of the birds of Africa except against a background of the vegetation, both present and past, as controlled by the factors responsible for the Pleistocene glaciations. Moreau's command of the available information on African birds, on all aspects of their habitat, and on the topographic and climatic history of the continent is impressive. One has the feeling, reading the book, that if existing information can provide the answer to a biogeographic question, the answer is in this book if birds are in any way involved. One can go the whole way in recommending the "mainland" part of the book.

Our readers, however, are interested in islands. Africa is surrounded by islands with every degree of isolation from the continent. Moreau has chosen to limit his remarks to islands reasonably close to the mainland, except for the oceanic Cape Verde group.

The chapter on the faunas of the West Coast islands is disappointing in that it seems a rather standard zoological discussion, with little of the remarkable ecological interpretation that permeates the earlier

parts of the book. This may very well be the result of the appalling degree of destruction of the native vegetation on most of these islands.

The bird fauna of Madagascar does not seem to be nearly as remarkable as its flora, though the degree of endemism is high and the recently extinct Aepyornithidae are remarkable enough. Moreau's rather short chapter on Madagascar is most interesting and attempts to find ecological explanation for the peculiarities of the fauna, but not altogether successfully.

A chapter follows on the Comoros, Mafia, Zanzibar and Pemba, with interesting bird faunas, and Sokotra, with a rather impoverished one. These are interpreted, if rather briefly, in terms of the ecology of the islands. It is disappointing that the Mascarenes, the Aldabra Group and the Seychelles are excluded, as they would provide logical extensions or attenuations to the ideas brought out in the discussions of the islands closer in toward the continental shore.

A general discussion of the island bird faunas brings out the interesting fact that in the African islands there is little of the adaptive radiation so characteristic of the faunas of Hawaii and the Galapagos. A succinct summary of the peculiarities of the African island faunas is offered at the end of the final concluding chapter.

<u>Nelson, B., Galapagos, islands of birds. 1-338, Wm. Morrow, New York, 1968. $7.95</u>. This is a very well-written, scientifically sound, though semi-popular account of a year spent studying the birds of these remarkable islands with detailed "portraits" of several of them, mostly sea birds, that will be of general interest on islands throughout the tropics.

<u>Brower, K., editor, Galapagos: the flow of wildness. 2 vols. Sierra Club, San Francisco, New York, London [1968]. $55.00</u>. These two magnificent large format volumes convey the magic, as well as the ecology and the evolutionary interest of "las Islas Incantadas" so effectively that, if after reading them, anyone could have any doubt that they should be preserved in this state for posterity to see and feel, it would show he had no sensitivity at all, or else that he had written off the likelihood of any significant posterity. The abundant and originally conceived color photos speak as loudly as the very well-written text. Recommended as a way to see the Galapagos for those who cannot see them otherwise, as an introduction for those who are going there, and as almost as good as a revisit for those who have been there already. John Milton's introduction to the second volume is also recommended as an introduction to conservation ecology for those to whom this may be a new idea.

<u>Philbrick, R. N., ed., Proceedings of the Symposium on the Biology of the California Islands. 1-363, Santa Barbara Museum, 1967</u>. The symposium of which this volume is a report was a very timely summing up of what is known on the 16 islands scattered off the west coast of California and Baja California (except the Farallones, which somehow were omitted). Their geology, geography, paleogeography, and especially biogeography were examined critically from many different scientific viewpoints, and

by a distinguished group of authorities who have studied the islands for many years. The volume should be of interest to anyone concerned with island biogeography and the evolution of insular organisms. It is of more than routine interest to your senior editor, since his initiation into island biology was on some of these very California islands.

Hoffmeister, J. E. and Multer, H. G., Geology and origin of the Florida Keys. G. S. A. Bull. 79:1487-1502, 1968. We commend this lucid discussion of the origin of our own domestic coral islands. The Key Largo Limestone is interpreted as the remnants of a reef-tract similar to the Florida Reef Tract of today, but which flourished about 95,000 years ago.

Fisher, R. L., Engel, C. G. and Hilde, T. W. C., Basalts dredged from the Amirante Ridge, western Indian Ocean. Deep-Sea Res. 15:521-534, 1968. This paper is not specifically on reefs or islands, but will be of great interest to those concerned with the origin of the western Indian Ocean atolls and with the biogeography of the region. Outstanding is a fold-in bathymetric chart of the area.

Piggott, C. J., A soil survey of Seychelles. Techn. Bull. 2, Land Resources Div., Dir. Overseas Surv., 1-89, Tolworth, Surrey, 1968. Although primarily on the high granitic Seychelles, this publication also treats the soils and geography of the atolls that are, or have been until recently, under Seychelles jurisdiction, extending south to include the Aldabra group and Farquhar. In addition to descriptions of the soils, with some attempt to relate them to Pacific atoll soils, there are climatic tables, soil profile data, and "A glossary of names of plants" in 3 appendices, brief descriptions and colored soil maps of the islands treated.

Perkins, R. D. and Enos, P., Hurricane Betsy in the Florida-Bahama area--geologic effects and comparison with Hurricane Donna. Jour. Geol. 76:710-717, 1968. We call this to the attention of those who share our interest in the effects of these severe storms on islands.

Kohn, A., Microhabitats, abundance and food of Conus on atoll reefs in the Maldive and Chagos Islands. Ecology 49:1046-1062, 1968. Reports results of a detailed study of the niches occupied, population densities, and food ecology of members of the predaceous mollusk genus Conus on several reefs. This is one of the building blocks from which an understanding of the coral reef ecosystem will eventually be constructed.

Shier, D. E., Vermetid reefs and coastal development in the Ten Thousand Islands, southwest Florida. G. S. A. Bull. 80:487-508, 1969. Geological study of reef-rock formed of masses of Vermetus shells, in an area where great ecological changes are threatened by large-scale "development" activities.

Weydert, P., Les variations recentes du niveau marin et leurs influences sur la morphologie recifale dans la Baie de Tulear (Sud-Ouest de Madagascar). C. R. Acad. Sc. Paris, D, 268:482-484, 1969. Ascribes present reef morphology to recent eustatic shifts in sea-level. A sample of the active work being carried on at the Tulear marine station.

Riesenberg, S. H., The native polity of Ponape. Smithsonian Contr. Anthrop. 10:1-115, 1968. This fine volume presents a part of the results of field work by the author and his associates in Ponape in 1947, 1948, 1953, 1954, and 1963. It is mainly a detailed account of Ponapean social organization, but interwoven with this are interesting data on material culture and much native vocabulary, including names of plants, animals and other material objects and concepts. Considerable general information is included as background.

Kiste, R. C., Kili Island: A study of the relocation of the ex-Bikini Marshallese. 1-393, Eugene, Ore., 1968. This is an exhaustive study of the recent history of the Bikini people, their displacement, several subsequent relocations, and current status. It is largely social and economic in its approach, but gives detailed attention to the geography and ecology of all the islands involved in the story, from Bikini to Rongerik, Kwajalein, Jaluit, and Kili. Plant lists (not too accurate), soils, fauna, and other resources are included. Many tables and diagrams are presented, as well as a detailed fold-in map of Kili Island, and small scale maps of the other atolls described. A small bibliography is given, perhaps more remarkable for its omissions than for what is included. This work has value both as historical record and as providing a hindsight account of the consequences of U. S. policies attendant on the arbitrary seizure of a dependent people's homeland. We would hope that it would become required reading for policy-makers and engineers engaged in major manipulations of the environment that involve transplantation of populations. It is good to have such consequences on record.

Wodzicki, K., The Tokelau rat survey 2. Follow-up Report. 18 April-15 June 1968. 1-35, 1-6, Wellington, N. Z., October 1968. This is a report on a re-survey, see ARB 126, p. 14, for a review of the first study. For some reason (perhaps so it can be carried in a hip pocket?) the text of the present report has been so reduced as to be almost unreadable. Luckily, our friend Dr. Wodzicki has a paper in press in the Proc. N. Z. Ecol. Soc. which we trust will be easier on the eye.

Glynn, P. W., Mass mortalities of echinoid and other reef flat organisms coincident with midday low water exposures in Puerto Rico. Marine Biology, Int. Jour. on Life in Oceans and Coastal Waters, 1(3):226-243, 1968. The low water exposures are linked to sudden reversal in the timing of diurnal tidal cycle in the spring and early summer. The author writes us that he is now making comparable observations on the Panama reefs.

Biotropica, the new journal of the Association for Tropical Biology, is scheduled for appearance in June 1969, with the second number to appear in autum of 1969. Manuscripts for consideration in Biotropica may deal with any phase of tropical biology and with related subjects so long as the primary emphasis is tropical and biological. Preference will be given to the presentation and discussion of original research or to those containing significant review and interpretive qualities. Information on Biotropica may be obtained from the editor, Dr. William L. Stern, Department of Botany, University of Maryland, College Park, Maryland 20742, U.S.A.

The ATB is an international society concerned with all phases of tropical biology. Members are kept up-to-date on happenings in tropical biology through an informative Newsletter which appears every other month. Lists of field trips, fellowship opportunities, research needs of members, and information on field stations are among the items to be found.

The Third International Symposium sponsored by the Association is to be held in Mayagüez, Puerto Rico, June 16-19, 1969. The symposium is entitled "Adaptive Aspects of Insular Evolution." Dr. Ernst Mayr, Museum of Comparative Zoology, Harvard University, has assembled a distinguished cast of participants and a stimulating format for discussion. The University of Puerto Rico, Mayagüez, is the host institution and Dr. J. A. Ramos, Director of Graduate Studies at the University, is chairman of the Organizing Committee.

Further information concerning membership in the Association and its activities may be obtained by writing to the Executive Director, Association for Tropical Biology, Smithsonian Institution, Washington, D. C. 20560, U.S.A.

Tropical Ecology, vol. 9, no. 2, Dec. 1968 has just been received. This is the official publication of the International Society for Tropical Ecology, with headquarters at the Department of Botany, Banaras Hindu University, Varanasi-5, India. The Treasurer, Chief Editor and Moving Spirit of the Society, Dr. R. Misra, writes this note to members: "I have great pleasure in placing before you the second number of Vol. 9 (1968) of Tropical Ecology. I hope you will note with satisfaction the improvement in the frequency, pagination and printing of the journal over preceding years. I wish to extend my sincere thanks and appreciation to the various members who have helped me in scrutinising the manuscripts received from time to time.

"During the last two years the financial position of the Society has improved considerably and with the active support of our members, it has been possible for the Society to publish the Proceedings of the Symposium on Recent Advances in Tropical Ecology on its own, though there has been much delay for unavoidable reasons. I wish to provide our members with more of material and increase the size of the journal to at least 400 pages per volume. Further, a wide coverage of ecological subjects related to the tropics is intended. Both research and review articles on plant, animal and human ecology, of terrestrial, fresh water and marine habitats, will find a place in the journal. To make the journal truly international as reflected by the constitution of the Editorial Board, I solicit your cooperation through contribution of articles for publication, and also by requesting your colleagues to become members of the Society."

Details on membership can be obtained from Dr. K. C. Misra, Secretary of ISTE, and orders for the Symposium ($18.00, 50% discount for members) as well as dues sent to him. Dr. F. R. Fosberg, President of ISTE, collects dues for the Americas only.

Biological Conservation: This new journal, published by Elsevier, Dr. Nicholas Polunin, Editor, has already had three issues (October 1968, January and April 1969) and contains a number of items on tropical islands and reefs. The first number included an article by D. R. Stoddart on The Aldabra Affair, an account of the campaign for the preservation of this remarkable island (see ARB 118, and article by Stoddart, The Conservation of Aldabra, in Geogr. Jour. 134: 471-486, December 1968), as well as a note by Dr. Polunin entitled: Seychelles Biological Sanctuaries? No. 2 offered an article on Conservation of island ecosystems in the South-West Pacific, by V. J. Chapman, and a note on an endemic Hawaiian Duck. No. 3 includes brief items on conservation of the Great Barrier Reef, of the Coral Reefs of Western Malaysia, and the raising of baby sea turtles as a means of preserving the species.

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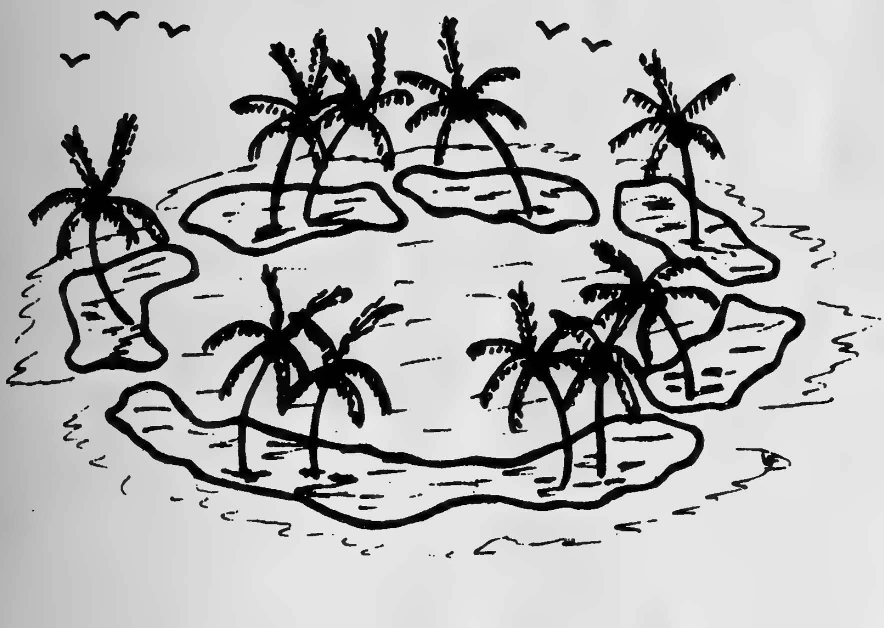

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Edited by

D. R. Stoddart

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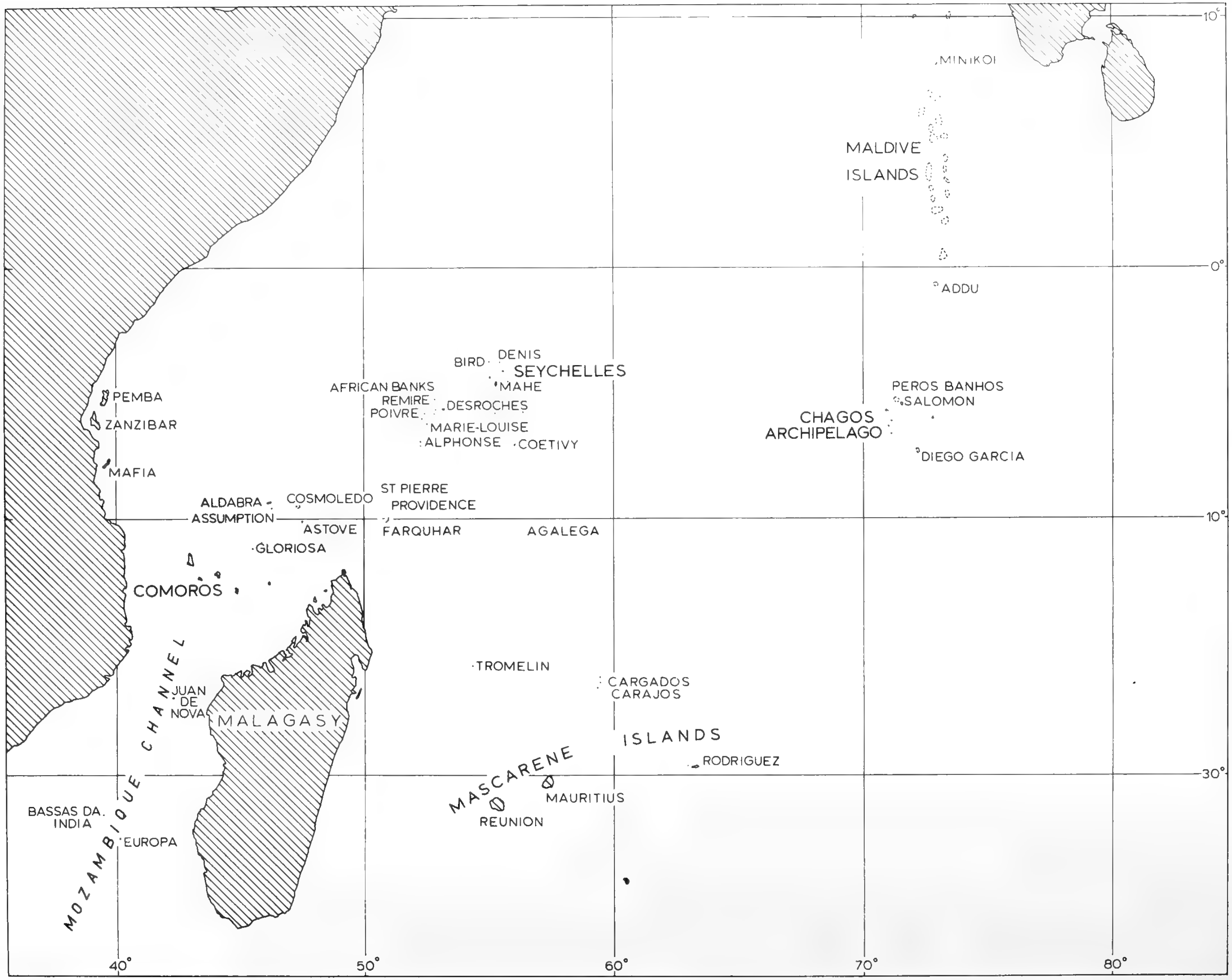

CORAL ISLANDS OF THE WESTERN INDIAN OCEAN

1. INTRODUCTION

D. R. Stoddart

As part of the programme of research on Aldabra Atoll in the southwest Indian Ocean, which began in August 1967 (Stoddart 1967, 1969a), it has been possible for parties from the Royal Society Expedition to Aldabra to visit other western Indian Ocean coral islands from time to time. These visits, though brief, have been important for two reasons. First, the arguments for the conservation of Aldabra itself for scientific research rested, at least in part, on a comparative analysis of the ecological status of neighbouring islands. Second, much of the available information on these islands is many decades old, and some have never been described. This series of reports aims first, therefore, to record the new information obtained during visits in 1967 and 1968 to seven such islands, and second, to provide succinct summaries and guides to the large but scattered literature, much of it taxonomic in nature, but which contains occasional references to them. In this way it is hoped to provide convenient accounts of these islands for the use of future workers, and also to indicate to visiting scientists at the Aldabra Research Station the possibilities for investigation of particular problems or particular groups elsewhere in the western Indian Ocean. A certain amount of repetition in bibliographical lists, acknowledgements etc., has been unavoidable to maintain the independence of the chapters on the different islands.

The coral islands of the western Indian Ocean (Figure 1) may be taken to comprise the following groups:

(a) the islands of the Mozambique Channel, including Europa;

(b) the Aldabra group, including Aldabra, Assumption, Cosmoledo and Astove;

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(c) the Farquhar group, comprising Farquhar, St Pierre and Providence;

(d) the Amirantes, including (from north to south) African Banks, Remire, D'Arros, St Joseph, Desroches, Poivre, Etoile, Boudeuse, Marie-Louise, and Desnoeufs;

(e) Bird and Dennis Islands, northern Seychelles Bank;

(f) Cargados Carajos;

(g) isolated islands, including Gloriosa, Agalega, Tromelin, Coetivy and Alphonse.

Most early navigators completely neglected the coral islands in the accounts of their travels. Thus Owen, who surveyed Farquhar and other islands in the 1820s, referred to the islands of the Amirantes simply as "low, sandy, sterile, and altogether insignificant" (Owen, 1833, II, 159), and neither he, nor Fairfax Moresby, after whose ships the Menai and Wizard islands on Cosmoledo Atoll are named, nor Wharton, who carried out the first thorough hydrographic survey in the 1870s, pay much attention to island form, vegetation or animal life. The first useful accounts are generally those dated from the period 1890-1910, by Abbott, Dupont and others. Two major expeditions, in H.M.S. Alert in 1882, to the Amirantes and Gloriosa, and by H.M.S. Sealark in 1905, to most of the western Indian Ocean islands, resulted in large collections and many records scattered through a large literature. While the collections in total were large, however, individual islands were often represented by small and inadequate collections. Gardiner (1936, Gardiner and Cooper 1907) contributed brief accounts of many islands to the Reports of the Percy Sladen Trust Expedition, and J. C. F. Fryer (1910) wrote useful accounts of Bird and Dennis Islands in addition to his work on the Aldabra group.

Apart from Vesey-FitzGerald's work in the 1930s, the most important subsequent investigations have been those of Baker (1963) and Piggott (1961, 1968), who visited all of the British-administered islands during a geological and soil survey in 1960, and of Gwynne, Wood and Parker, who collected plants and birds during a cruise in 1967 (Gwynne and Wood 1969). Summaries of the earlier work on Assumption, Astove, Gloriosa, Cosmoledo, Farquhar, St Pierre and Providence were published by Stoddart (1967b).

The present series of studies is based on visits by Royal Society Expedition personnel to Farquhar, Cosmoledo, Astove, Assumption, Desroches, Remire, and African Banks. In addition, there have been excellent recent reports on Europa Island (Legendre 1966) and on Cargados Carajos Shoals (Staub and Guého 1968). Gibson-Hill (1952) summarised data from Agalega, and Brygoo (1955) published observations on Tromelin. These western Indian Ocean studies are linked with others

in the central Indian Ocean, in the southern Maldives (Stoddart 1966) and in the Chagos Archipelago (Stoddart and Taylor, in preparation). These permit some preliminary generalisations on regional variation in Indian Ocean reefs and islands (Stoddart 1969b).

Important gaps remain, however, even at the level of the summary reports presented in this Bulletin. Though large collections of marine and terrestrial fauna were made at Coetivy in 1905, there is no account of this island available. There has been no study in this century of Gloriosa (though Guilcher and others (1965) give aerial photographs), in spite of its probable importance in the colonisation of the Aldabra group from Malagasy. Apart from the three islands discussed here, there is no account of the fauna and flora of the Amirantes, and our knowledge of Agalega is very patchy. Tromelin has been among the least well known of all these islands; the account included here (Staub 1970) follows a visit to the island in 1968 by M. France Staub of Curepipe, Mauritius.

It is, of course, unfortunate that more comprehensive accounts were not compiled seventy years ago, for Coppinger, Abbott, Gardiner and others were able to give tantalising references to island features then largely unaltered by man. Since that time the sandy islands have been almost entirely planted with coconuts, and the rocky islands generally devastated by surface guano mining. The effect of the latter on island ecology is well illustrated by Assumption, though the case of Remire suggests that at least partial recovery is possible over a period of a few decades, but endemic species once extinct cannot be brought back. It is possible that more information on the former state of these islands still exists in manuscript form or in Government archives: we have, for example, been fortunate to have had the loan of diaries and papers belonging to Mr H. A'C. Bergne and Sir John Fryer, dating from 1900-1910, which contain important information on the islands they visited. There is no doubt that modern work can now in many cases only record the state of island ecologies intensely disturbed and modified by man, and with the exception of marine life it is now difficult to attempt to reconstruct the state of island ecosystems before human exploitation began.

The islands treated in this report fall into two main groups: (a) elevated reef-limestone islands, including Cosmoledo, Astove and Assumption, which share many of the characteristics of Aldabra; and (b) sand cays on sea-level reefs, including Farquhar, Desroches, Remire and African Banks. They also experience considerable variation in rainfall, though records have not been kept on any of them except Assumption and Tromelin. Interpolation from known island records (Stoddart 1969b) suggests that Cosmoledo, Astove and Assumption have 1000 mm or less per annum, Farquhar about 1200 mm, and Desroches, Remire and African Banks, in the northern Amirantes, about 1500 mm.

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Specific acknowledgements and thanks are given in many individual papers in this Bulletin, but I wish to thank here the following:

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The Lessees and Managers of the islands visited, for their hospitality and assistance during our short visits.

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2. GEOGRAPHY AND ECOLOGY OF FARQUHAR ATOLL

D. R. Stoddart and M. E. D. Poore

Introduction

Farquhar Atoll (10°11'S, 51°07'E) lies 285 km northeast of Madagascar and 1150 km from the coastline of Africa. It is roughly triangular in shape, with an area of 170 sq km. Apart from small sand cays on the northern rim (Iles des Déposés, du Milieu, Lapin) dry land is confined to the eastern or windward side. Total land area, by planimetry from Figure 2, is 7.5 sq km or 4.4 per cent of the area of the atoll.

The first chart of Farquhar was made by Margaro in 1776 and published, with additions by W. F. W. Owen in 1824, as Admiralty Chart 718 in 1878. This chart is very rudimentary. The atoll was surveyed by Cdr W. J. L. Wharton in 1878, with a large-scale survey of the lagoon entrance by Lt. J. T. A. White, and these surveys formed the basis of a revision of Chart 718 in 1879. Wharton's survey, with some recent additions, is the basis of present charts; it is detailed only for the northern rim and the eastern islands. Figure 2 is based on air photograph cover of the atoll flown in 1960, with topographic control and bathymetry from the Admiralty chart: while reef features are shown in detail, this map should not be used for navigational purposes.

The first biological observations on record are those of Fairfax Moresby in 1822, but these remained unpublished. The Percy Sladen Expedition spent three days on Farquhar in 1905, when Stanley Gardiner worked over North Island, especially the seaward reef, and the entomologist Bainbrigge Fletcher, over South Island. The collections made were small and heterogeneous; determinations published for various groups in the Percy Sladen Expedition Reports are listed, with citations, in Table 1. Most attention was given during this visit to the insects, and Table 2 lists the determinations on insects, by orders and families, in the Expedition Reports. Collections made in some groups, such as the corals, remain unpublished; other groups were neglected. Thus it is difficult to gain an impression of the ecology of Farquhar from the work of the Percy Sladen team.

Apart from a visit in 1937 by Vesey-FitzGerald, who reported on the birds (1940, 1941), little further work was done on Farquhar until

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Fig. 2. Farquhar Atoll. Data reproduced from BA Chart No. 718 with the sanction of the Controller, HM Stationery Office and of the Hydrographer of the Navy.

the 1960s. The atoll was visited in 1960 by the geologist B. H. Baker and the agronomist C. J. Piggott, and though no collections were made several useful accounts were published (Baker 1963, 80-85; Piggott 1968, 56-57; Piggott, unpublished, 48-53). In 1967 M.F.R.V. *Manihine* called at Farquhar with a party collecting for the National Museum, Nairobi, and including I. S. C. Parker, D. Wood and M. D. Gwynne; birds and plants were collected (Gwynne and Wood 1969, Parker 1970). On 19 September 1968 *Manihine* revisited Farquhar with a Royal Society party comprising T. S. Westoll, M. E. D. Poore and D. R. Stoddart. Stoddart and Poore traversed North Island, Iles Manahas, and the northern half of South Island, and visited Goelette; plants were collected and observations made on birds. In spite of the brevity of these visits, and of the others listed in Table 1, it is possible to give some account of the ecology of the atoll, and to indicate areas in which more detailed work is required.

Table 1. Scientific Studies at Farquhar Atoll

Date		Study	Reference
1504		Discovered by João de Nova; named after him.	
1776		Charted by M. Margaro	Adm.Ch.718(1878)
1821	May	Lieut. Hay, schooner Eliza	
1822	March 12	Lieut. Hay, Wizard and Menai	Moresby (1842)
1822	July 26	Visit by Fairfax Moresby, bird notes	Stoddart and Benson (1969)
1824		Chart additions by W. F. W. Owen; renamed after Sir R. Farquhar, Governor of Mauritius	Adm.Ch.718(1878)
1831		Further charting by Lt Hay	
1867		French chart by M. Lieutard	Ann.hydrograph. (1868, 32)
1878		Hydrographic chart by W. J. L. Wharton	Adm.Ch.718(1879)
1905	Sept. 28-Oct. 2	Percy Sladen Expedition: J. S. Gardiner, C. F. Cooper, T. B. Fletcher	Gardiner and Cooper (1907), Gardiner (1936)
1937		L. D. E. F. Vesey-FitzGerald, bird studies, economic insects	Vesey-FitzGerald (1940, 1941)
1956		W. Travis, underwater and general observations	Travis (1959)
1957	Dec. 7	W. D. Hartman, land birds	Hartman (1958)
1960	Sept. 26-29	B. H. Baker (geology) and C. J. Piggott (soils)	Baker (1963) Piggott (1961, 1968)
1961	Sept. 28-Oct. 3	P. O. Wiehe, plants	Fosberg and Renvoize, this issue
1967	Oct. 3	M. D. Gwynne, D. Wood, I. S. C. Parker, collections of plants and birds	Parker (1970); Gwynne and Wood (1969)
1968	Sept. 19	D. R. Stoddart, M. E. D. Poore, T. S. Westoll, collection of plants, observations of geomorphology and birds	This report

Geomorphology

Lagoon and reefs

Knowledge of the reefs and submarine topography comes entirely from hydrographic surveys and aerial photographs (Figure 2), but it is clear that Farquhar lagoon is one of the most complex in topography and presumably in geomorphic history in the world. Three main divisions may be noted: (1) the main lagoon basin, 17 km long and with a greatest width of 7.5 km; (2) a triangular area on the south side, extending 4.5 km southwards from the rim of the main lagoon basin; and (3) a submerged spur at the northwest corner, extending for 7 km northwestwards with depths of 11-30 m.

The main lagoon basin is crossed by a series of narrow continuous ridges, up to 5 km long, trending approximately NE-SW. Air photographs suggest that these are not active reefs at the present time. These ridges divide the basin into three parts: a western part with apparently smooth floor at depths of 10-15 m, with hardly any reef knolls; a central part with very numerous knolls and patches, and depths probably about 8-10 m; and an eastern part with ridges and few knolls, and depths of 4-11 m. The southern triangular extension is crowded with knolls and patches, with deep holes of up to 16.5 m. The southern reef flat here is wide, with much coral growth around broad shallow entrances. Nothing is known of the northwest extension apart from the bathymetry shown in Figure 2.

The asymmetry of the shallow features of the atoll is thus marked; it is emphasised further by the character of the peripheral reef. The eastern reef flat is rocky, straight, and tidally emergent; it is largely covered with detrital islands. The reef on the south side is apparently actively growing, and its flat is low enough for coral growth. The reef flat on the west and north sides is poorly defined, with only small patches rising to intertidal levels. Air photographs show that the peripheral reef flats, both of the main basin and of the southern triangle, truncate structures within the lagoon. Thus lagoonal ridges near Goelette and South Island pass into reef flat deposits, and in the southern triangle debris sheets from the reef front are burying reef knolls in the back reef area.

There is only one entrance to the lagoon, a narrow channel 6-10 m deep near the north point, though much water must enter the lagoon over the windward reef flat south of Goelette and leave over the leeward reefs.

Bottom topography seaward of the peripheral reefs is also unusual. On the eastern side depths of less than 30 m are found between 1 and 2.5 km from the reef edge, though the floor then falls more steeply to depths of hundreds of metres. Along the north coast the zone less than 30 m deep is 1 km or less wide, though broadening at the northwest point.

These features are impossible to interpret without field investigation, but they probably result from a complex history, possibly involving differential movement or tilting of the atoll itself. The central oval lagoon is probably an old feature, though its linear ridges are uncommon in atoll lagoons elsewhere. The straight windward reef appears to be retreating lagoonward, truncating lagoon features and leaving a shelf at 20-30 m to seaward. It is possible that the southern triangular reef area is a recent addition to the atoll, perhaps formed by reef growth on a former submarine spur similar to that now extending to the northwest. The sharp distinction in the main lagoon between ridges, apparently largely reefless, and the adjacent deeper floor may result from karst erosion of old reef ridges during Pleistocene low sea level stands.

There is no information on the modern reefs. Gardiner (1936, 432-433) noted the absence of a boulder zone and fissured (algal) zone on the eastern reef flat, which he correctly stated was a rock flat with few corals. He described *Heliopora* and *Porites* in the lagoon, together with much *Cymodocea*. Living reefs are certainly damaged by frequent tropical cyclones, and some effects are described by Travis (1959, 69-73).

Islands

The eastern reef flat has a width of 1-1.5 km, and the islands standing on it are of simple form and structure. South Island, the largest, is 5.7 km long, 0.6-0.9 km wide, and has an area of 3.9 sq km. The crescentic North Island measures 8.5 km in length along its axis, is 0.2-1 km wide, and has an area of 3.2 sq km. Most of South Island is formed of dunes, both active coastal dunes up to 20 m high (Plate 1), and older inland dunes forming a hummocky surface. The lagoon shore of South Island is formed by a wide sand ridge, in places enclosing infrequently-flooded unvegetated areas (Plate 2), floored with poorly-sorted sands and gravels, which resemble the *barachois* of the Chagos atolls. On North Island the dunes are lower, and are found in the centre and on the lagoon side of the island as well as on the seaward side. Beaches are generally sandy, with local beachrock on the lagoon side up to 1 m above low water level (Plate 3). Seaward beaches on North Island are eroding (Plate 4), with resulting truncation of vegetation zones: dune faces are also eroding both on North Island and at the north end of South Island. Lagoon beaches by contrast are prograding (Plate 5). The only cobble beach seen was on the north side of South Island, facing the channel between it and the Manahas. Gravel is found in places on the island surfaces and on the floors of the South Island *barachois*, but is not common.

The three small Manahas islands are of considerable physiographic interest. Each is a cay of sand and gravel, resting on a platform of cemented cay deposits which extends up to 200 m seaward of the islet (Plate 6). The platform outcrops along the sides of channels between the islets, where it has a width of only a few metres, and

resembles outcrops of clastic rocks on the sides of similar channels (hoa) in the Tuamotu atolls. Such a conglomerate platform, which is quite distinct from the intertidal reef platform, was not seen on the main islands, except patchily on the lagoon shore of North Island, but may be forming beneath them as a cay sandstone. The surface of the Manahas conglomerate stands about 0.5 m above high water level, and is fretted by subaerial erosion.

Goelette is a small flat featureless island with seaward beaches of imbricate cobbles; it consists of sand and gravels, partly phosphatised (Baker 1963, 85). It has no beachrock. There are several small islets on the northern reef, but they have not been visited.

Gardiner (1936, 432) claimed to find "evidence in isolated masses of rock on the outer sides of the encircling reef, and especially on the islets, of an almost continuous or quite continuous reef that stood up for 10 feet or more above the water level, and formerly surrounded the whole bank, apparently about covering the existing reef". If these features exist they may be storm-cast reef-blocks: no trace of them was seen in 1968, though elevated reef-rock would be expected if the history of the atoll has been as complex as the lagoon bathymetry suggests.

Piggott (1968) distinguishes four soil series on the Farquhar islands: (1) the Farquhar Series, developed on fine dune sands; (2) Shioya Series, on non-dune calcareous sands; (3) small areas of phosphatic hardpan soil described as Jemo Series, though differing in some respects from the type Jemo Series described by Fosberg (1954); and (4) a small area of Saline Marsh on South Island. The parent materials of the Farquhar Series are relatively homogeneous, finer and more angular than those of Shioya Series, and Farquhar Series soils are generally developed on rolling topography with a deep water table. Parent materials of Shioya Series range from sands to gravels. Baker (1963) has given analyses of guano and phosphatic rock from Piggott's Jemo Series.

Tropical cyclones are common on Farquhar, and major storms occurred in 1893, 1926, 1950 and 1954. Apart from their effects on reefs, these storms have led to beach erosion, cutting back of dunes, and the mantling of island surfaces with coarse deposits.

Vegetation

Though plants were collected on Farquhar by Fletcher during the Percy Sladen Expedition in 1905, no list was ever published. The following paper by Fosberg and Renvoize describes collections made by Gwynne and Wood in October 1967 and by Stoddart and Poore in September 1968. The latter collection totalled 62 species of flowering plants, one moss and one lichen, to which can be added ten species of flowering plants recorded as sight records only. Gwynne and Wood (1969) record 47 species, including 16 sight records.

Both flora and vegetation differ markedly from those of elevated limestone islands in the Aldabra group, and resemble more those of the sand cays of the Amirantes and the central Indian Ocean. No rainfall records have been kept, but with probably 1200 mm/yr Farquhar is considerably wetter than Aldabra and Assumption. Both the raised limestone community and the mangrove community are absent on Farquhar. The islands are simple sand cays with dunes, but the vegetation, though characteristic of such habitats, is complicated by a long history of human interference, with the result that there is a strong gradient in number of introduced species southwards from the settlement on the North Island. The channel between North and South Islands forms a major break in this gradient, and though both of the main islands are largely covered with coconuts, North Island has many more introduced species of herbs and grasses in the ground layer than has South. Nesting seabirds also influence the vegetation, particulary on the smaller islands. Farquhar is affected by a major cyclone about once in 25 years, when the littoral vegetation and also the trees, especially the coconuts, are subject to major damage.

Nine vegetation types can be distinguished on Farquhar on the basis of our brief reconnaissance in 1968:

(1) Seaward beach without dunes: where the beach is stable there is a hedge of *Scaevola*, *Tournefortia*, *Pemphis* and *Suriana*; where the beach is retreating, inland species such as *Casuarina* are found at the beach crest.
(2) Seaward coastal dunes: these are covered with a mosaic of *Suriana*, *Scaevola* and *Tournefortia*, with *Fimbristylis* and *Portulaca*.
(3) Inland stable dunes: mainly under coconuts and *Casuarina*, with a ground cover of grasses (Plates 7, 8 and 9).
(4) Inland sand or fine gravel areas, under coconuts or *Casuarina*, with considerable diversity in ground cover (Plate 10).
(5) Lagoon beach, mainly edged by *Scaevola*, *Suriana* and *Pemphis*.
(6) Barachois, edged by *Pemphis* and *Suriana*, with a sparse irregular cover of grasses and sedges.
(7) Inland depressions with standing water or wet ground. These are uncommon; one on North Island has a solitary *Rhizophora*.
(8) Herb mat community dominated by *Boerhavia* and *Achyranthes*, found in the tern-nesting area on Goelette Island.
(9) Vegetation in the main settlement and also adjacent to individual houses elsewhere, dominated by introduced decorative and cultivated plants.

North Island

The vegetation of North Island has been much affected by recent cyclones: the seaward beach has eroded, and many coconuts and *Casuarina* trees have been broken inland. The main vegetation type is coconut woodland in the flatter inland areas. Apart from *Casuarina* and, especially in the north, wild *Carica papaya* (Plate 11), few other trees

are present, and those which are found are concentrated near the lagoon shore beach hedge. They include Cordia subcordata, a Ficus, and Hernandia sonora, none of them common; Guettarda speciosa and Thespesia populnea were not seen. According to Piggott (1968, 36) wild Carica is an indicator of phosphatic soils, and groves of this species were growing wild on North Island as early as 1905 (Gardiner and Cooper 1907, 144).

The sward beneath the coconuts is extremely variable, more especially in the north where it is clearly frequently cut. In addition to grasses (Cenchrus echinatus, Digitaria horizontalis, Stenotaphrum dimidiatum, Dactyloctenium aegyptium, Chloris barbata) and sedges (Fimbristylis cymosa, Cyperus dubius, Cyperus ligularis), and the vine Cassytha, there are more than twenty species of flowering plants present. Those collected include:

Achyranthes aspera	Parthenium hysterophorus
Bidens pilosa	Passiflora suberosa
Boerhavia diffusa	Phyllanthus amarus
Euphorbia hirta	Phyllanthus maderaspatensis
Euphorbia prostrata	Portulaca oleracea
Gynandropsis gynandra	Sida cf. parvifolia
Ipomoea tuba	Stachytarpheta jamaicensis
Kalanchoe pinnata	Striga asiatica
Laportea aestuans	Tribulus cistoides
Launaea intybacea	Turnera ulmifolia
Lippia nodiflora	Vernonia cinerea

Turnera is particularly conspicuous in many places, but often there is a very diverse assemblage with no single dominant. The fern Nephrolepis biserrata is present and locally abundant on the ground.

The coconuts are generally 10-12 m tall. In the middle of the island many are snapped off and crownless (Plate 8). Newly planted coconuts towards the southern end are 2-3 m tall. Mature Casuarina trees throughout the island reach 20 m in height.

The seaward beach on North Island is sandy and retreating (Plate 4). Broken, sometimes dead, juvenile Casuarina line much of the beach crest, with a zone of spindly Scaevola taccada to landward. Pemphis is also found on the seaward beach. The ground under the shrubs is often bare, but Triumfetta procumbens was collected on the beach itself. The lagoon shore is prograding, with a dense hedge of Scaevola taccada and Suriana maritima, and occasional trees of Casuarina and Cordia.

Dunes carry a distinctive vegetation. On active dunes, as at the southern tip of the island, there is a shrub layer of bushy Scaevola taccada 1.5 m high, with a largely bare ground surface dotted with rosettes of Fimbristylis cymosa and Eragrostis: the ground here is being eroded by wind and the sedges and grasses stand on small

pinnacles. Non-active dunes are common over the island and carry mature Casuarina woodland with a mixed ground vegetation.

One small marshy area in the centre of the island contains a solitary tall Rhizophora, the only mangrove seen on Farquhar, with a dense ground cover of Stenotaphrum.

The main settlement at the north end of North Island contains several trees not seen elsewhere, in addition to tall Casuarina and Hernandia sonora. These include Ochrosia oppositifolia, Moringa oleifera, Terminalia catappa, Calophyllum inophyllum, and Tabebuia pallida, the last a New World decorative. Cultivated plants of economic value include Gossypium hirsutum, Agave, Musa, Ricinus communis, various cucurbits, and maize; decoratives include a red-flowered Opuntia, Catharanthus roseus, Bidens sulphurea, Heliotropium indicum, Solanum cf. melongena, Malvastrum coromandelianum, Gaillardia lanceolata and Zinnia elegans. The whole area of the settlement has the appearance of long-continued human occupation and alteration.

Manaha Islands

These three small islets between North and South Islands are covered with a tall woodland of Cocos and Casuarina. Each has a littoral hedge of Tournefortia argentea, Scaevola taccada and Suriana maritima. The ground vegetation beneath the coconuts consists of abundant vines of Ipomoea tuba, clumps of Fimbristylis cymosa, and little else. The contrast with the diversity of similar ground vegetation on North Island is very striking.

South Island

Like North Island, South Island has a small settlement, not permanently occupied, at its northern end; a large part of the island is covered with dunes; and most of the rest by coconut or Casuarina woodland. In the coconut woodland few other trees are present (rare Hernandia sonora and Cordia subcordata) and there are few shrubs. The ground cover is similar to that under coconuts on North Island, but fewer species are present. Grasses include Eragrostis sp., Cenchrus echinatus, and Dactyloctenium aegyptium; the sedges Fimbristylis cymosa and Cyperus ligularis. Other flowering plants noted in the ground layer include:

Achyranthes aspera
Boerhavia diffusa
Cassytha filiformis
Euphorbia prostrata
Ipomoea tuba
Kalanchoe pinnata
Malvastrum coromandelianum
Phyllanthus amarus
Portulaca cf. australis
Sida sp.
Striga asiatica
Turnera ulmifolia
Vernonia cinerea

A single bryophyte, collected on the surface of old dunes in heavy shade, can only be determined as *Bryum* sp. or *Pohlia* sp. by C. C. Townsend.

The seaward dunes are covered with a dense growth of *Scaevola taccada*, with *Suriana maritima* and some *Tournefortia argentea*. The lagoon beach is lined mainly with *Scaevola* and *Suriana*, and the long inlets or *barachois* by *Suriana* and *Pemphis acidula*. The lichen *Usnea* was collected from *Suriana* on the margins of one of the *barachois*.

The small settlement has introduced trees, particularly *Moringa oleifera* but also including a single young *Barringtonia asiatica*. *Musa* sp., *Ricinus communis* and *Amaranthus dubius* are cultivated, and the decoratives include *Mirabilis jalapa* and *Gaillardia lanceolata*.

Goelette Island

The tern-breeding island of Goelette is almost devoid of trees (one *Cocos* and one *Casuarina*, both small and sickly) and shrubs (some low *Suriana maritima* and *Tournefortia argentea* on the northwest shore). Almost the whole island is covered with a low mat of *Ipomoea pes-caprae* vines, the sedges *Fimbristylis cymosa* and *Cyperus ligularis*, and especially *Boerhavia diffusa* and *Achyranthes aspera*, the latter forming the tallest vegetation apart from the rare trees and shrubs. No species not present elsewhere on the atoll were found on Goelette, but the absence of *Stachytarpheta jamaicensis*, dominant in similar bird colonies on Desnoeufs, Amirantes (Ridley and Percy 1955), and present on North Island, may be noted.

Fauna other than Birds

Both the land and marine fauna of Farquhar are very inadequately known, for apart from Gardiner's party in 1905 no attention has been paid to any group except the birds. Gardiner's own collections were small by comparison with those he made on other islands during the Percy Sladen Expedition. A single marine alga is recorded (Gepp and Gepp 1909), but the collections of marine fauna, other than pelagic forms, are very small (Table 2). Gardiner and Cooper (1907, 144-145) described the Green Turtle nesting on Farquhar, and it still does so.

According to Rothschild (1915) the Giant Land Tortoise *Geochelone gigantea* formerly existed on Farquhar but has become extinct. No evidence for this statement is known, either historically or in the fossil record. However, two Giant Tortoises from Aldabra are present on North Island: one of these was seen in 1968, in the coconut woodland near the south end of the island, and is considerably larger than any tortoise now living on Aldabra, presumably in response to the wetter climate, richer vegetation, and absence of competition. Boulenger (1909) recorded two reptiles, a *Hemidactylus* and a *Phelsuma*, but neither was seen in 1968. Two crabs (*Cardisoma*, *Coenobita*) are

Table 2. Marine Fauna recorded from Farquhar Atoll

Group			Number of species	Reference
Coelenterata	Hydroids		4	Jarvis (1922)
	Siphonophorae		19	Browne (1926)
	Medusae		8	Browne (1916)
	Alcyonaria		1	Thomson and Mackinnon (1910)
Annelida	Polychaeta		1	Potts (1910)
Echinodermata			3	Bell (1909)
Crustacea	Decapoda	Anomura	1	Laurie (1926), Borradaile (1907)
		Brachyura	1	Borradaile (1907), Rathbun (1911)
	Stomatopoda		5	Tattersall (1912)
Mollusca	Gastropoda		4	Melvill (1909)
	Pteropoda		8	Tesch (1910)
	Heteropoda		4	Tesch (1910)

recorded by Borradaile (1907), and nine species of Arachnida (Neumann 1907, Hirst 1911). There are no native mammals. Bainbrigge Fletcher collected insects in 1905, and this accounts for the 66 species of insects recorded in the Percy Sladen Reports: citations of Farquhar material in these Reports are keyed in Table 3.

Table 3. Insects recorded from Farquhar Atoll by the Percy Sladen Expedition

Group	Number of Species	Reference
Apterygota	1	Carpenter (1916)
Orthoptera	9	Bolivar (1912, 1924)
Dermaptera	2	Burr (1910)
Hemiptera	7	Distant (1909, 1913), Green (1907)
Neuroptera	1	Needham (1913)
Lepidoptera	16	Fletcher (1910), Fryer (1912), Meyrick (1911)
Coleoptera	18	Arrow (1922), Champion (1914), Fleutiaux (1923), Gebien (1922), Grouvelle (1913), Scott (1912)
Hymenoptera	11	Cameron (1907), Cockerell (1912), Forel (1907), Meade-Waldo (1912)
Diptera	1	Lamb (1922)

It is clear from this record that little can be said about the invertebrate fauna of Farquhar, either marine or terrestrial, without further collecting.

Birds

Breeding land birds

The number of land birds is very small by comparison with that on the elevated limestone islands, and all four species recorded may have followed human settlement. Apart from a possible *Alectroenas*, now extinct (Stoddart and Benson 1970), and a dubious sighting of "a solitary and shy warbler which I could not identify" by Travis (1959, 66), the native land bird fauna of Farquhar may have been nil. The following species are recorded.

Foudia madagascariensis
Native according to Gardiner, introduced according to Hartman (1958). Common everywhere, especially on North Island in 1968.

Streptopelia picturata
Recorded (as *Turtur picturatus*) as "very common in Farquhar", probably introduced from Madagascar, by Gadow and Gardiner (1907, 107). No other record known; not seen in 1968.

Geopelia striata
Introduced before 1905 and then common around North Island settlement (Gardiner and Cooper 1907, 144). ♂ collected on North Island by Parker, 3 October 1967. Common, especially on the northern half of North Island, 1968.

Bubulcus ibis
♀ collected on Goelette by Parker, 3 October 1967. Breeding in *Suriana* bushes on Goelette, September 1968; six adult birds.

Possibly resident shore birds

Ardea cinerea
Sight, Manahas, September 1968.

Butorides striatus
Sight, North Island, September 1968.

Migrants

Arenaria interpres
Sight, Manahas, September 1968.

Squatarola squatarola
As *S. helvetica* in Gadow and Gardiner (1907), 1 specimen.

Charadrius alexandrinus
Sight record, as *Aegialitis cantiana*, in Gadow and Gardiner (1907).

Limosa lapponica
1 specimen taken, 1905 (Gadow and Gardiner 1907).

Crocethia alba
Sight, Manahas, September 1968.

Erolia testacea
♀ collected by Parker, Goelette, 3 October 1967.

Dromas ardeola
Sight, Manahas, September 1968.

Other species are recorded from Providence Bank by Watson and others (1963, 187). Charadrius leschenaultii and Numenius phaeopus in particular are likely to occur.

Sea birds

The main sea bird breeding ground is on Goelette Island (Plates 14, 15 and 16), and has been exploited in the past for terns' eggs (Ridley and Percy 1955). Vesey-FitzGerald (1941, 525) recorded that "about 25,000 birds [Sterna fuscata] were reared in 1937 after heavy egg-collecting" on this island; he also recorded Sterna sumatrana and roosting Anous tenuirostris. Travis (1959, 62-63) found few if any Sooty Terns on Goelette, the whole being covered with Noddies, but the time of year of his visit is not clear. Parker in October 1967 collected four species of terns (Sterna albifrons, S. fuscata, S. sumatrana, S. dougalli) on Goelette, and saw Thalasseus bergii. He found several thousand young Sooty Terns on the island, all more than half fledged and the majority fully fledged, and he noted a large number of dead or dying birds (Parker 1970). A large number of Noddies Anous stolidus also nest on Goelette, but were already fledged at the time of Parker's visit. In September 1968 we found many thousands both of Sterna fuscata and Anous stolidus on Goelette, in large discrete flocks. Again most of the terns were fledged, and there were large numbers of dead birds. The whole island was covered with ticks (Amblyomma sp.?), in contrast to similar bird colonies on African Banks.

The only other sea bird definitely known to nest on Farquhar is the Red-footed Booby Sula sula. Travis (1959, 64-65) records nesting boobies with chicks in Casuarina on the east side of South Island. This colony was seen, in tall Casuarina stained white by the birds, on the lagoon shore of South Island in 1968. Other sea birds may nest on the small remote sand cays of the northern reef, but these have not been investigated.

The following sea birds have been recorded from Farquhar:

Sula dactylatra
Recorded by Vesey-FitzGerald (1941) from Goelette.

Sula sula

Recorded from South Island by Vesey-FitzGerald (1941) and Travis (1959), and seen in 1968. Breeds in Casuarina.

Fregata minor

Sight, September 1968; not common.

Sterna dougallii

♀ collected by Parker on Goelette, 3 October 1967.

Sterna sumatrana

Recorded by Vesey-FitzGerald (1941) on Goelette; ♂♂ collected by Parker on Goelette, 3 October 1967.

Sterna fuscata

Breeds in thousands on Goelette. Recorded by Vesey-FitzGerald (1941) and later visitors. ♂♀♀ collected by Parker on Goelette, 3 October 1967.

Sterna albifrons

♀♀♀♂♂♂ collected by Parker on Goelette, 3 October 1967.

Anous stolidus

Recorded by Parker on Goelette; present in thousands in September 1968.

Anous tenuirostris

Recorded as roosting on Goelette by Vesey-FitzGerald (1941).

Gygis alba

Recorded by Stoddart and Poore, September 1968: probably the "small white gull" noted by Moresby in 1821-2 (Stoddart and Benson 1969).

Settlement

Farquhar was discovered by Joao de Nova in 1504, but apart from the French hydrographic survey in 1776 and the British in 1824, nothing is known of its history until the early nineteenth century. The atoll was apparently uninhabited when a ship named the St Abbs was wrecked there in 1855, though Lieut. Hay had found a fishing settlement established on 12 March 1822 (Moresby 1842, 680). A small fishing station was established soon afterwards (Lieutard 1868), and planting of coconuts followed: a considerable number were planted on North Island by a Mauritian firm in 1870 (Findlay 1882, 546-547). According to a visiting Stipendiary Magistrate (reported in Bergne 1900), however, coconut trees were not bearing by 1879. At this time the population numbered 40 men, with an export of salt fish and turtle valued at Rs 14,000. More coconuts were planted by James Spurs about 1885 (Gardiner and Cooper 1907, 143), but many were destroyed in the

cyclone of 1893. In 1895 the coconuts which survived were in full bearing, producing about 70,000 nuts per month, and supporting a population of 100 men, women and children (Bergne 1900). Planting began on South Island as late as 1905 (Gardiner and Cooper 1907, 143).

Piggott (1961, 82) has summarised the history of the coconut plantations. By 1950 they were yielding 30 tons of copra per month. 30,000 trees were destroyed, however, in the major cyclone of that year. In spite of replanting, copra production in 1960 was only 20 tons per month, and 24 tons in 1967.

The settlement (Plate 17) in 1968 consisted of 39 people, all resident on North Island, with 31 head of cattle, 2 donkeys, and 2 horses, pigs, chickens, turkeys, ducks, geese and bees. Maize has been cultivated at least since 1905. The economic development of the atoll is limited both by the recurrent cyclones and by the great distance to Mahé, in both respects comparing unfavourably with competing plantations in the Amirantes and on Coetivy.

From 1814, when Mauritius came under British rule, Farquhar was administered as part of the Colony of Mauritius, and while the new Colony of Seychelles was formed in 1903, Farquhar was not transferred to it until December 1921. In 1965 Farquhar was detached from the Seychelles and became part of the British Indian Ocean Territory. As such it is covered by the provisions of an agreement between Britain and the United States governing the use of B.I.O.T. for defence purposes for a period of not less than fifty years.

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1. *Scaevola* community on high dunes, north end of South Island

2. Unvegetated *barachois*, lagoon shore, north end of South Island

3. Cay sandstone outcrop on eroding lagoon shore, North Island

4. Scaevola and Casuarina on eroding seaward shore, North Island

5. Prograding lagoon shore with Scaevola and Casuarina, North Island

6. Conglomerate platform outcropping on the sides of the channel between the northern Manaha Island and North Island; view towards the lagoon

7. Open <u>Casuarina</u> woodland on old dunes, North Island

8. Woodland of <u>Cocos</u> and <u>Casuarina</u> on old dunes, North Island; note the hurricane damage to coconuts

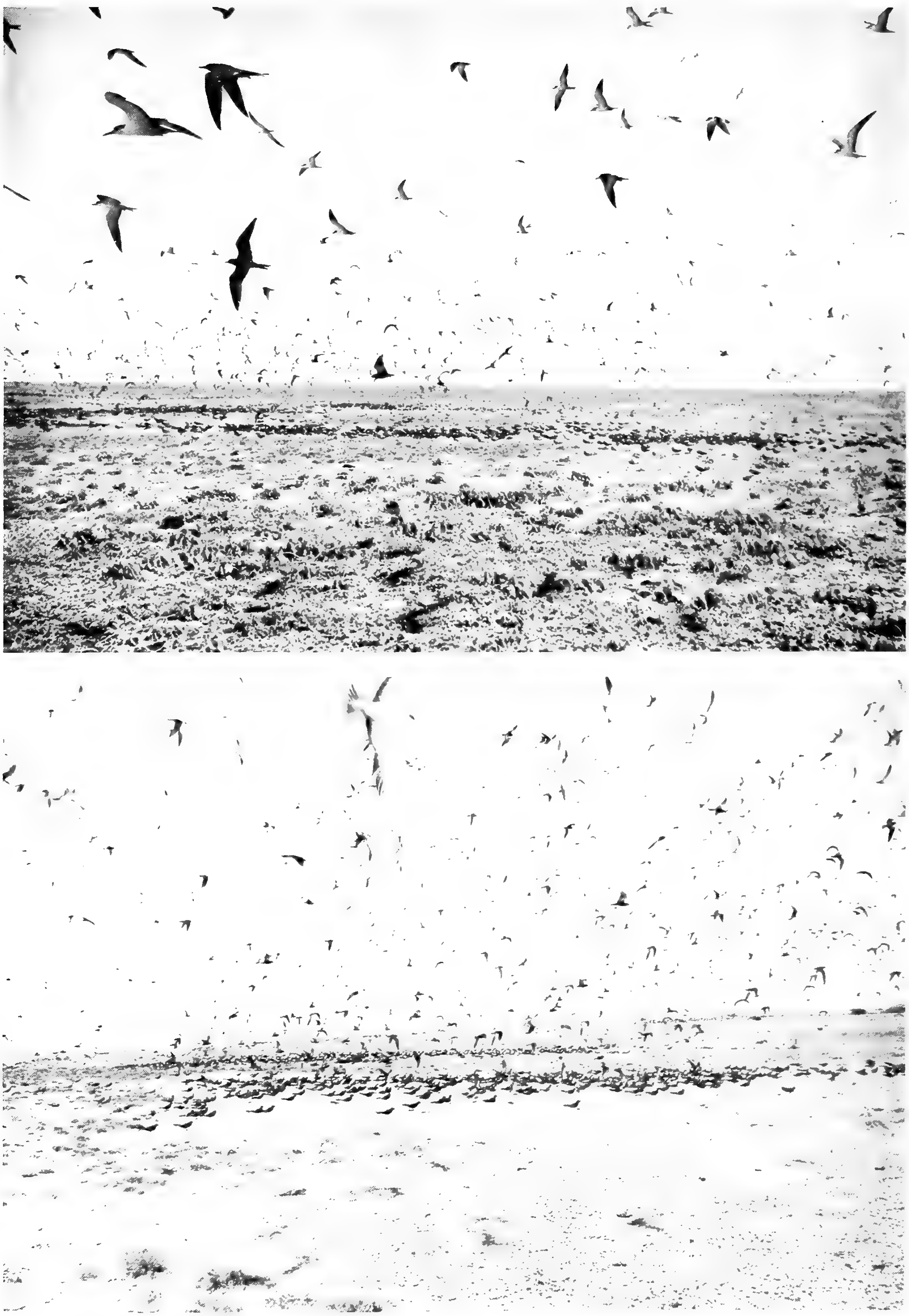
9. Replanting of coconuts in hurricane-damaged area of North Island

10. Open woodland of Cocos with Fimbristylis on flat gravel spread, North Island

11. Coconut woodland with grove of wild Carica papaya, north end of North Island

12. Sooty Terns and Noddies on Goelette Island. Note the low herb-mat vegetation, and the scarcity of dwarf shrubs

13-14. Sooty Terns and Noddies on Goelette Island. Note the low herb-mat vegetation, and the scarcity of dwarf shrubs



15-16. Sooty Terns and Noddies on Goelette Island. Note the low herb-mat vegetation, and the scarcity of dwarf shrubs

17. Copra sheds at Settlement, North Island

3. PLANTS OF FARQUHAR ATOLL

F. R. Fosberg and S. A. Renvoize

USNEA sp.
South I., Stoddart & Poore 1368 (K). On Suriana.

Unidentified moss
Stoddart & Poore s. n.

NEPHROLEPIS BISERRATA (Sw.) Schott
S. 1., Wiehe 10174 (MAU)*; North I., Stoddart & Poore 1342 (K, US); Gwynne & Wood 1179 (EA).

CYMODOCEA CILIATA Ehrenb. ex. Aschers.?
South I. "Alt. 10 ft", Gwynne & Wood 1216 (EA).
Small, internodes condensed, leaf-tips sharply and prominently denticulate.

THALASSIA HEMPRICHII (Ehrenb.) Aschers.
South I., Gwynne & Wood 1216 (EA). (Fragment mixed with Cymodocea coll.)

CENCHRUS ECHINATUS L.
South I., Gwynne & Wood 1201 (K, EA); North I., Stoddart & Poore 1341 (K).

CHLORIS BARBATA Sw.
North I., Stoddart & Poore 1364 (K).

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
S. 1., Wiehe 10162 (MAU); North I., Stoddart & Poore 1361 (K, US); South I., seen by Stoddart, 1968.

DIGITARIA TIMORENSIS (Kunth) Bal.
South I., Gwynne & Wood 1202 (K, EA): North I., Stoddart & Poore 1357 (K, US)

DIGITARIA sp.
Wiehe 10163 (MAU)

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*Wiehe collections cited from Mauritius Herbarium have not been seen by the authors.

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ELEUSINE INDICA (L.) Gaertn.
South I., Gwynne & Wood 1200 (K, EA), 1206 (EA).

ERAGROSTIS sp.
S. 1., Wiehe 10178 (MAU); North I., Stoddart & Poore 1360 (K); South I., seen by Stoddart, 1968.

LEPTURUS REPENS R. Br.
North I., Gwynne & Wood 1186 (EA).

PANICUM MAXIMUM Jacq.
S. 1., Wiehe 10179 (MAU); South I., Gwynne & Wood 1203 (EA).

PANICUM (near) UMBELLATUM Trin.
S. 1., Wiehe 10183 (MAU).

PASPALUM DISTICHUM L. (P. vaginatum Sw.)
S. 1., Wiehe 10187 (MAU); North I., Gwynne & Wood 1182 (K, EA).

PENNISETUM POLYSTACHION (L.) Schult.
North I., Stoddart & Poore 1332 (K, US).

PENNISETUM PURPUREUM Schum.
S. 1., Wiehe 10160 (MAU); North I., Gwynne & Wood 1184 (EA).

STENOTAPHRUM DIMIDIATUM (L.) Brongn.
S. 1., Wiehe 10161 (MAU); North I., Stoddart & Poore 1359 (K, US).

STENOTAPHRUM MICRANTHUM (Desv.) Hubb.
S. 1., Wiehe 10159 (MAU); South I., Gwynne & Wood 1197 (EA).

ZEA MAYS L.
South I., seen by Stoddart, 1968.

CYPERUS DUBIUS Rottb.
S. 1., Wiehe 10165 (MAU): North I., Stoddart & Poore 1348 (K, US); South I., seen by Stoddart, 1968.

CYPERUS KYLLINGIA Endl.
North I., Gwynne & Wood 1183 (EA): Stoddart & Poore 1334 (K, US).

FIMBRISTYLIS CYMOSA R. Br.
S. 1., Wiehe 10164 (MAU); North I., Gwynne & Wood 1181 (EA); Stoddart & Poore 1349 (K); South I., Gwynne & Wood 1213 (EA); Stoddart & Poore 1370 (K, US); Manaha Islets, seen by Stoddart, 1968.

COCOS NUCIFERA L.
North, South, and Manaha Islets, seen by Stoddart, 1968.

AGAVE SISALANA Perr.
North I., seen by Stoddart, 1968.

MUSA SAPIENTUM L.
North and South Islets, seen by Stoddart, 1968.

CASUARINA EQUISETIFOLIA L.
North, South, and Manaha Islets, seen by Stoddart, 1968.

LAPORTEA AESTUANS (Gaud.) Chew
North I., Stoddart & Poore 1344 (K).

FICUS BENGHALENSIS L.
North I., Stoddart & Poore 1336 (K, US); Gwynne & Wood 1188 (EA).

BOERHAVIA DIFFUSA L.
S. 1., Wiehe 10173 (MAU); North I., Gwynne & Wood 1185 (EA); Stoddart & Poore 1352 (K, US); South I., Gwynne & Wood 1211 (K, EA).

MIRABILIS JALAPA L.
South I., Gwynne & Wood 1199 (EA); Stoddart & Poore 1371 (K, US).

ACHYRANTHES ASPERA L.
S. 1., Wiehe 10172 (MAU); North I., Stoddart & Poore 1346 (K, US); South I., Gwynne & Wood 1189 (K, EA).

AMARANTHUS DUBIUS Mart. ex Thell.
North I., Stoddart & Poore 1324 (K, US); South I., seen by Stoddart, 1968.

AMARANTHUS sp.
S. 1., Wiehe 10190 (MAU).

PORTULACA cf. AUSTRALIS Endl.
South I., Stoddart & Poore 1369 (K).

PORTULACA OLERACEA L.
S. 1., Wiehe 10193 (MAU); South I., Gwynne & Wood 1205 (EA); North I., Stoddart & Poore 1328 (K, US).

PORTULACA sp.
S. 1., Wiehe 10177 (MAU).

CASSYTHA FILIFORMIS L.
S. 1., Wiehe 10196 (MAU); North I., Stoddart & Poore 1321 (K, US); South I., seen by Stoddart, 1968.

HERNANDIA SONORA L.
North I., Stoddart & Poore 1345 (K, US); South I., seen by Stoddart, 1968.

GYNANDROPSIS GYNANDRA (L.) Briq.
S. 1., Wiehe 10167 (MAU); South I., Gwynne & Wood 1204 (K, EA); North I., Stoddart & Poore 1343 (K, US).

MORINGA OLEIFERA Lam.
North I., Settlement, Stoddart & Poore 1379 (K, US); South I., seen by Stoddart, 1968.

KALANCHOE PINNATA (Lam.) Pers.
North I., Stoddart & Poore 1322 (K, US); South I., seen by Stoddart, 1968.

DESMANTHUS VIRGATUS Willd.
S. 1., Wiehe 10184 (MAU).

INDIGOFERA sp.
S. 1., Wiehe 10175 (MAU).

LEUCAENA LEUCOCEPHALA (Lam.) de Wit
North I., Gwynne & Wood 1186 (K, EA).

TRIBULUS CISTOIDES L.
North I., Stoddart & Poore 1339 (K, US); South I., Gwynne & Wood 1193 (K, EA).

SURIANA MARITIMA L.
North I., Gwynne & Wood 1187 (EA); Stoddart & Poore 1333 (K, US); South and Manaha Islets, seen by Stoddart, 1968.

ACALYPHA INDICA L.
S. 1., Wiehe 10192 (MAU) "first observed after 1950 cyclone"; North I., Settlement, Stoddart & Poore 1382 (K).

EUPHORBIA HIRTA L.
S. 1., Wiehe 10188 (MAU); South I., Gwynne & Wood 1198 (EA); North I., Stoddart & Poore 1354 (K).

EUPHORBIA PROSTRATA Ait.
North I., Stoddart & Poore 1355 (K); South I., seen by Stoddart, 1968.

PEDILANTHUS TITHYMALOIDES (L.) Poit.
North I., Stoddart & Poore 1326 (K).

PHYLLANTHUS AMARUS Schum. & Thonn.
North I., Stoddart & Poore 1350 (K); South I., seen by Stoddart, 1968.

PHYLLANTHUS MADERASPATENSIS L.
S. 1., Wiehe 10170 (MAU); South I., Gwynne & Wood 1212 (EA); North I., Stoddart & Poore 1362 (K, US).

PHYLLANTHUS (near) TENELLUS Roxb.
S. l., Wiehe 10189 (MAU).

RICINUS COMMUNIS L.
North and South Islets, seen by Stoddart, 1968.

TRIUMFETTA PROCUMBENS Forst.
North I., Stoddart & Poore 1329 (K, US).

ABUTILON sp.
S. l., Wiehe 10198 (MAU).

GOSSYPIUM HIRSUTUM L.
S. l., Wiehe 10186 (MAU); South I., Gwynne & Wood 1191 (K, EA).

MALVASTRUM COROMANDELIANUM (L.) Garcke
S. l., Wiehe 10191 (MAU); North I., Settlement, Stoddart & Poore 1378 (K, US); South I., Stoddart & Poore 1367 (K, US).

SIDA PARVIFOLIA DC.
North I., Stoddart & Poore 1327 (K, US); South I., Gwynne & Wood 1210 (K, EA).

CALOPHYLLUM INOPHYLLUM L.
North I., Settlement, Stoddart & Poore 1384 (K).

TURNERA ULMIFOLIA L.
S. l., Wiehe 10169 (MAU); North I., Stoddart & Poore 1351 (K, US); South I., seen by Stoddart, 1968.

PASSIFLORA FOETIDA var. HISPIDA (DC.) Killip
S. l., Wiehe 10189 (MAU).

PASSIFLORA SUBEROSA L.
North I., Stoddart & Poore 1366 (K, US).

CARICA PAPAYA L.
North I., seen by Stoddart, 1968.

CUCURBITA cf. MAXIMA Duch. ex Lam.
North I., Stoddart & Poore 1323 (K, US).

CUCURBITA PEPO L.
South I., Gwynne & Wood 1190 (EA).

MELOTHRIA MADERASPATANA (L.) Cogn.
North I., Stoddart & Poore 1340 (K); South I., Gwynne & Wood 1194 (K, EA); Ile Goelette, Gwynne & Wood 1219 (EA).

PEMPHIS ACIDULA Forst.
S. l., Wiehe 10197 (MAU); North I., Gwynne & Wood 1180 (K, EA); Stoddart & Poore 1330 (K, US).

RHIZOPHORA MUCRONATA Lam.
North I., Stoddart & Poore 1331 (K, US).

TERMINALIA CATAPPA L.
North I., Settlement, Stoddart & Poore 1381 (K).

BARRINGTONIA ASIATICA (L.) Kurz
South I., Stoddart & Poore 1386 (K, US).

OPUNTIA FICUS-INDICA (L.) Mill.
North I., photo by Stoddart, 1968 (determination verified by Lyman Benson, 1969).

CATHARANTHUS ROSEUS (L.) G. Don
North I., Stoddart & Poore 1338 (K, US).

OCHROSIA OPPOSITIFOLIA (Lam.) K. Schum.
North I., Settlement, Stoddart & Poore 1385 (K).

IPOMOEA TUBA (Schlecht.) G. Don
S. 1., Wiehe 10200 (MAU); Goelette I., Gwynne & Wood 1218 (EA); North I., Stoddart & Poore 1337 (K, US); South I., Gwynne & Wood 1209 (K, EA); Manaha Islets, seen by Stoddart, 1968.

CORDIA SUBCORDATA Lam.
North I., Stoddart & Poore 1335 (K, US); South I., seen by Stoddart, 1968.

HELIOTROPIUM INDICUM L.
North I., Settlement, Stoddart & Poore 1375 (K, US).

TOURNEFORTIA ARGENTEA L. f.
North and South and Manaha Islets, seen by Stoddart, 1968.

LIPPIA NODIFLORA (L.) Michx.
S. 1., Wiehe 10166 (MAU); North I., Stoddart & Poore 1365 (K, US).

STACHYTARPHETA JAMAICENSIS (L.) Vahl
S. 1., Wiehe 10180 (MAU); North I., Stoddart & Poore 1358 (K, US).

SOLANUM MELONGENA L.
North I., Settlement, Stoddart & Poore 1376 (K).

SOLANUM NIGRUM L.
North I., Settlement, Stoddart & Poore 1383 (K).

STRIGA ASIATICA (L.) O. Ktze
S. 1., Wiehe 10195 (MAU); North I., Stoddart & Poore 1347 (K, US); South I., seen by Stoddart, 1968.

TABEBUIA PALLIDA (Lindl.) Miers
North I., Settlement, Stoddart & Poore 1380 (K).

ASYSTASIA BOJERIANA Nees
S. 1., Wiehe 10182 (MAU).

SCAEVOLA TACCADA (Gaertn.) Roxb.
North, South, and Manaha Islets, seen by Stoddart, 1968.

BIDENS PILOSA L.
S. 1., Wiehe 10194 (MAU); North I., Stoddart & Poore 1363 (K, US).

BIDENS SULPHUREA (Cav.) Sch.-Bip.
North I., Settlement, Stoddart & Poore 1374 (K).

GAILLARDIA LANCEOLATA Michx?
South I., Stoddart & Poore 1372 (K, US), 1373 (K, US); Gwynne & Wood 1207 (K, EA), 1208 (K, EA).

LAUNAEA INTYBACEA (Jacq.) Beauv.
S. 1., Wiehe 10181 (MAU); North I., Stoddart & Poore 1325 (K).

PARTHENIUM HYSTEROPHORUS L.
S. 1., Wiehe 10185 (MAU); South I., Gwynne & Wood 1195 (EA); North I., Stoddart & Poore 1353 (K, US).

SPILANTHES sp.
S. 1., Wiehe 10176 (MAU).

VERNONIA CINEREA (L.) Less.
S. 1., Wiehe 10171 (MAU); South I., Gwynne & Wood 1196 (EA); North I., Stoddart & Poore 1356 (K, US).

ZINNIA ELEGANS Jacq.
North I., Settlement, Stoddart & Poore 1377 (K).

4. AN OLD RECORD OF A BLUE PIGEON ALECTROENAS SPECIES AND SEA-BIRDS ON FARQUHAR AND PROVIDENCE

D. R. Stoddart and C. W. Benson

While working on manuscripts in the Old Indian Office, London, Stoddart found the following statement in a document about voyages in the southwest Indian Ocean in 1821-22, written by Captain (later Admiral of the Fleet Sir) Fairfax Moresby:

> "Jean de Nova i.e. Farquhar and Providence ... like the Amirantes, Coetivy and Alphonse are the resort of Millions of Birds of which, the Frigate Bird, the Fou, a beautiful small white gull, a variety of various coloured Gannet, and the Tropic Bird are the principle: In S. Pierre and Providence a species of small blue pigeon are in great abundance, and so seldom disturbed that they do not fly at Man's approach, but are knock'd down with Sticks, we found them excessively good eating, these birds build and nest on the Mapou tree and other Dwarf trees which cover the surface of the islands ..."

The "small blue pigeon" must have been a species of Blue Pigeon, *Alectroenas*. We know of no other reference to its occurrence on Farquhar, Providence or St Pierre. Stoddart spent 19 September 1968 on Farquhar, traversing most of the atoll land (see maps in Stoddart and Poore 1970 and Watson, Zusi and Storer 1963, 184), but saw no blue pigeons. The genus *Alectroenas* is endemic to the Malagasy Region. It was formerly represented on Mauritius, and is still so on Malagasy (Madagascar), the Comoros, Aldabra and the Seychelles (Goodwin 1967, 380-384). There may also have been a form on Rodriguez, *A. rodericana* (Milne-Edwards), known only from bones (Hachisuka 1953, 180). According to Rountree and others (1952, 187), the Mauritius form, *A. nitidissima* (Scopoli), became extinct about 1831, though Renshaw (1939) gives the date as early as 1826. Penny (1967, 272) writes of the "declining numbers" and edibility of *A. pulcherrima* (Scopoli) in the Seychelles. The Comoro form, *A. s. sganzini* (Bonaparte), was reported by Benson (1960, 52) as very confiding and excellent eating, though still plentiful. Nevertheless representations were made at the Conference of the International Council for Bird Preservation in New York in 1962 for its proper protection (IX Bull. I.C.B.P., 1963, 38, 41). We can confirm that on Aldabra *A. sganzini minor* Berlepsch is extremely confiding. It is still plentiful in the southeast of the atoll. Tameness and palatability, both mentioned in Moresby's account, were undoubtedly the undoing of *Alectroenas* on St Pierre and Providence, and presumably Mauritius too.

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Of the other species (sea birds) mentioned in Moresby's account, Watson and others (1963, 185-188) mention neither frigatebirds Fregata spp. nor tropicbirds Phaethon spp. "Fou" is French for a gannet, so that it would appear that there were at least two Sula spp. Watson and others (1963) list both S. dactylatra and sula as breeding on Farquhar. The "beautiful small white gull" was presumably the Fairy Tern Gygis alba, which according to Watson and others (1963) breeds on Providence.

Acknowledgement

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5. GEOGRAPHY AND ECOLOGY OF COSMOLEDO ATOLL

C. J. Bayne, B. H. Cogan, A. W. Diamond, J. Frazier, P. Grubb,
A. Hutson, M. E. D. Poore, D. R. Stoddart, J. D. Taylor

Introduction

Cosmoledo Atoll, 9°41'S, 47°35'E, is located 110 km east of Aldabra. It consists of eight main islands and numerous islets on the atoll rim, surrounding a large and open lagoon. The two largest islands, Wizard and Menai, are those usually visited by scientists. There has been no detailed survey of Cosmoledo at any time, though many expeditions have called there for brief visits (Table 4). The main published accounts are those by Dupont (1907, 8-12), Fryer (1911, 428-430), Travis (1959, 111-156), Baker (1963, 86-92), and Piggott (1961, 27-30; 1968, 53-54). Ten members of the Royal Society Expedition to Aldabra visited Menai and Wizard Islands in March 1968, and five more visited Menai only in September 1968: this paper summarises earlier work and adds new information from the Royal Society surveys.

The main hydrographic survey of Cosmoledo was by W. J. L. Wharton in 1878, published as Admiralty Chart 718 in 1879. This chart, with revisions by H.M.S. *Owen* in 1964, is still current. The atoll was covered by aerial photography in 1960, and Baker (1963, 87, 89, 91, 93) used air photographs to prepare sketch maps of the geology of the main islands. Figure 3 is based primarily on the 1960 air photograph cover, with topographic control and bathymetry from the 1967 edition of Admiralty Chart 718. This map should not be used for navigational purposes without further field survey.

Geomorphology

Cosmoledo stands on the northern of two presumably volcanic peaks, 45 km apart, rising from the ocean floor at 4000-4400 m depth. At the 4000 m isobath the volcanic massif is 85 km long N-S and 33-52 km wide: the Cosmoledo peak becomes distinct from that on which Astove stands at a depth of 1000 m (Figure 4). Outside the peripheral reef of Cosmoledo, the sea floor falls gently to 50 m, over a distance of 0.5-1 km, and then more steeply: the 500 m isobath generally lies 1-1.5 km from the surface reefs.

The atoll has maximum dimensions of 14.5 x 11.5 km, and a total area of 152 sq km. The peripheral reef flat varies in width from 1 to 2.5 km, averaging about 1.5 km, and encloses a shallow lagoon, opening to the south in two major channel systems. The greatest depths in the lagoon

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Table 4. Scientific Studies at Cosmoledo Atoll

Date	Study	Reference
1822 July 31	Capt. F. Moresby in ships *Wizard* and *Menai*	Moresby (1822)
1875 Oct. 17	Capt. Niejahr, *Hermann Friedrich*	Niejahr (1876)
1878	Hydrographic survey by W. J. L. Wharton	Adm. Ch. 718 (1879)
1895	Agricultural survey by S. C. E. Baty	Bergne (1900)
1901 Oct. 9-12	Visit by H. A'C. Bergne	Bergne (1901)
1906	Chart emendations by L. Ferrari	
1907	H. L. Thomasset, insects	
1908 Sept. 1-5	J. C. F. Fryer: general observations, insects	Fryer (1911, 428-30)
1906 Sept. 14-19	R. Dupont: plants, insects	Dupont (1907, 8-12)
1937 Sept.-Nov.	L. D. E. F. Vesey-FitzGerald: vegetation, birds	Vesey-FitzGerald (1940,1941,1942)
1953 Nov.	Italian Zoological Expedition: C. Prola, F. Palombelli, F. Prosperi, S. Nievo	Berio (1956)
1956	H. Legrand: Lepidoptera	Legrand (1965)
1957 Dec. 10-12	W. D. Hartman: land birds	Hartman (1958)
1959 Oct.9-Nov.27	H. Legrand, M. Gerber: Lepidoptera	Legrand (1965)
1960 Oct.9-12	B. H. Baker, geology; C. J. Piggott, soils	Baker (1963); Piggott (1961,1968)
1964	R. E. Honegger: birds, reptiles	Honegger (1966, unpub. a, unpub.b)
1964 March 13-14	H.M.S. *Owen*; Cmdr D. W. Haslam: survey, birds	Bourne (1966)
1967 Oct. 5-6	M. D. Gwynne, D. Wood, I. S. C. Parker: plants, birds	Parker (1970); Gwynne and Wood (1969)
1968 March 6	C. W. Benson, B. H. Cogan, A. W. Diamond, F. R. Fosberg, J. Frazier, A. Graham, P. Grubb, A. Hutson, K. McKenzie, S. A. Renvoize	This report; Benson (1970); Fosberg and Renvoize (1970)
1968 Sept. 14	C. J. Bayne, J. C. Gamble, M. E. D. Poore, D. R. Stoddart, T. S. Westoll	This report

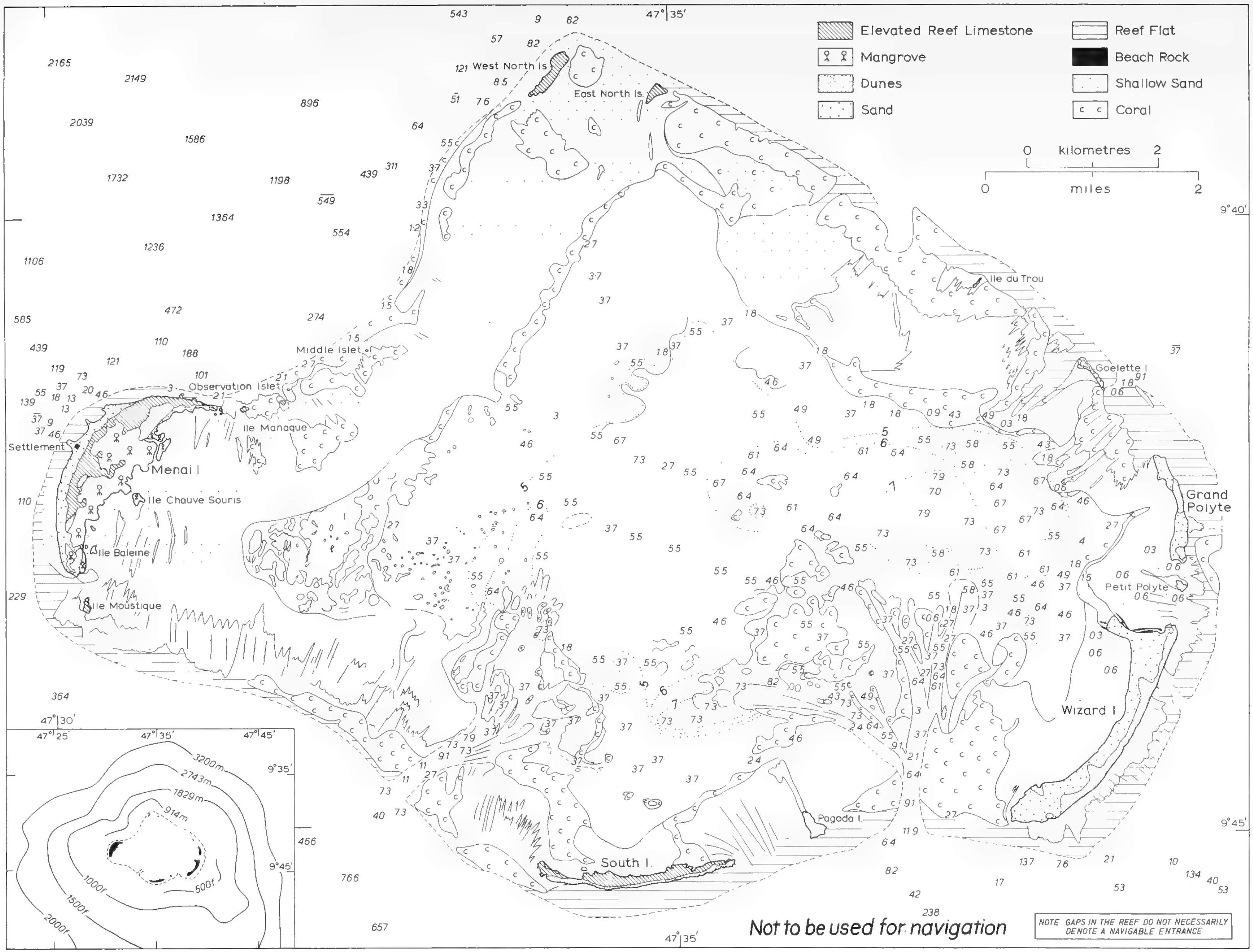

Fig. 3. Cosmoledo Atoll. Data reproduced from BA Chart No. 718 with the sanction of the Controller, HM Stationery Office and of the Hydrographer of the Navy.

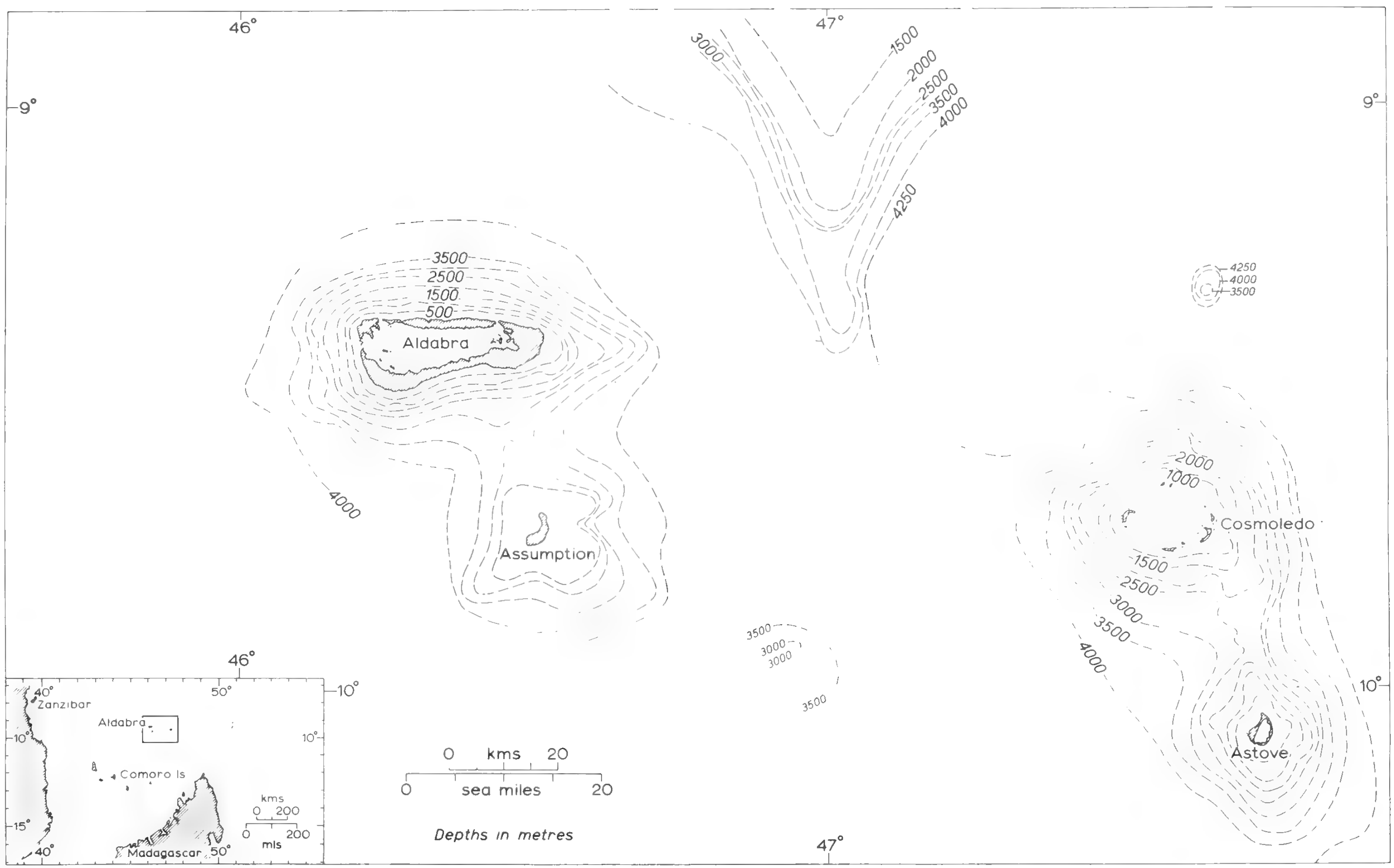

Fig. 4. The Aldabra Group

are found at the inner ends of these two channels and in the channels themselves, though where these bifurcate and disappear there is much coral growth between the branches with depths of less than 1 m. Most of the central lagoon basin is more than 5 m deep; a small area at the head of the southwest channel reaches more than 6 m, and a larger area at the head of southeast channel more than 7 m. Maximum recorded depth is 8.2 m. Coral growth is important only around the branching channel systems and also where the lagoon narrows towards Menai Island, here forming a reticulate reef network similar to that at Hitaddu, Addu Atoll. Irregularities on the lagoon floor can be seen on air photographs, but the general simplicity of form and absence of knolls and patches contrasts markedly with the Farquhar lagoon. Maximum depths in the main channels range from 5 to 11 m; other passages through the peripheral reef which are navigable by small boats do not intersect the reef flat itself, and have depths of 1 m or less.

There are eight main islands on the atoll rim, with numerous small islets; the total land area is approximately 5.2 sq km, or 3.4 per cent of that of the whole atoll. Wizard Island (Grande Ile), on the windward side of the atoll, is 3.2 km long and has an area of 1.6 sq km. It consists of low elevated reefrock largely covered with sand and gravel, and with coastal dunes on the seaward side up to 17 m high. The crests of these dunes are aligned parallel to the prevailing Trades, and Baker (1963) states that reefrock pavement is exposed in the dune slacks. The seaward beach, at least in the centre, consists of sand and cobbles overlying a smooth inclined rock pavement, rising from a potholed and eroded reef flat. The central part of the island is formed by a sand plain, and the lagoon shore is a gently sloping sand beach with, in places, ledges of reef limestone.

Menai Island on the lee side has a land area of 2.3 sq km. The area of raised reefrock is larger than on Wizard. On the seaward side the rock reaches 2-4 m in height, forming undercut headlands separated by sandy beaches. The rock declines in height to about 1 m on the lagoon side, where there is a large area of mangrove. Several dune areas are located between the reefrock and the mangrove, and the dunes at the south point, about 8-10 m high, are still active. Older vegetated dunes at the north end rise to 10-15 m. On the seaward side the raised reefrock is partly covered with sand, and north of the settlement the old undercut cliffline is fronted by a wide area of recent sand. The elevated reefrock at the south point is a massive reef limestone with much *Acropora*; it resembles the main Aldabra limestones but there is no inland ridge at about 8 m as on Aldabra. There is probably no basis in fact for Niejahr's (1876, 244) report of lava blocks on Menai.

The other islands of the atoll rim were not visited by Royal Society parties, but Piggott (1961) visited North, Grand Polyte, Pagoda and South Islands. North Island he describes as being formed entirely of eroded champignon, with some sand on the south side, the whole formerly covered with guano, now largely scraped away and remaining only in holes. Grand

Polyte, about 250 m wide, is formed in the north of raised reefrock standing about 1.6 m above high water, and in the south of sandy flats; central dunes rise to about 5 m. South Island, about 200 m wide, consists entirely of raised reef limestone.

The soils of the Cosmoledo islands can be classed into Piggott's (1968) main soil series: most of the islands, especially on rock, are covered with phosphatic Desnoeufs Series with a very shallow A horizon; Farquhar Series soils are forming on dunes; and in some areas there are soils approximating to Shioya Series, but always mixed with dune sands.

Vegetation

The flora of Cosmoledo is similar to that of Aldabra, and plants collected in 1968 and by Gwynne and Wood (1969) in 1967 are listed by Fosberg and Renvoize (1970). Three main vegetation types can be distinguished: (1) raised reefrock vegetation; (2) sand vegetation, including dunes; and (3) mangrove vegetation. The raised reefrock vegetation has some of the species present on Aldabra, and notably *Pemphis*, *Sideroxylon* and *Ficus*, with *Sarcostemma*, but the small area, degree of human interference, and lack of investigation combine to explain the absence in recent records of such characteristic species as *Lomatophyllum* and *Solanum*. Sand vegetation has been much affected by man, except for the littoral vegetation of *Scaevola*, *Tournefortia* and *Suriana*. Most of the sand areas, except the dunes, support coconuts, with a ground cover of grasses, sedges, herbs and vines, including many introduced weeds and cultivated species. Stable dunes are covered either with *Casuarina* woodland or with a scrub of *Scaevola* and *Suriana*. The mangrove vegetation is tall and includes at least six species: *Avicennia marina*, *Rhizophora mucronata*, *Bruguiera gymnorhiza*, *Sonneratia alba*, *Xylocarpus granatum* and *Ceriops tagal*. Apart from the extension of coconut woodland and attendant introduction of aliens on the sand areas, and the clearing of reefrock vegetation during guano digging on the North Island, the vegetation of Cosmoledo has probably changed little since Moresby (1822, 30) recorded that "here we saw a few Cocoa Nut trees, the Mapou *Pisonia*, some *Latannia*, and trees that resemble the Filahoe *Casuarina* of the Mauritius".

Recent observations of vegetation are available only for Menai and Wizard Islands. Piggott (1961) mentions a mixed scrub with *Pemphis* and much wild cotton on raised reefrock at North Island, with *Scaevola* on recent sand. He again found a *Pemphis* scrub on reefrock on Grand Polyte, and the same species on the dunes and also on the southern sand flats, together with *Scaevola* and *Tournefortia*. On the raised reefrock of South Island he describes "a few *Pemphis* and *Pisonia grandis* (mapou) shrubs but little other vegetation".

Menai Island

The seaward shore of Menai has a characteristic beach-crest hedge of Scaevola taccada, Tournefortia argentea and Suriana maritima, with Cordia subcordata on the landward side of the hedge. Pemphis acidula is found on rocky headlands. The vegetation of the sandy area north and south of the settlement is most diverse. Cocos nucifera is common though patchy in its distribution. Tall Casuarina equisetifolia is found at the settlement itself; this species was noted by Moresby in 1822, and Fryer (1908) found it "apparently of great age" sixty years ago. Guettarda speciosa, Cordia subcordata, Thespesia sp., and Grewia salicifolia are the only other trees noted. Scattered shrubs are more numerous near the southern end of the island, where they include Allophylus africanus (3 m tall), Premna obtusifolia (4 m), Azima tetracantha, Acalypha claoxyloides, and Caesalpinia major; north of the settlement we also noted Vernonia aldabrensis. The ground cover is very diverse. North of settlement Fimbristylis cymosa is dominant; to the south there is a cover of grasses (Eragrostis sp., Dactyloctenium aegyptium, Lepturus repens), sedges (Fimbristylis cymosa, Cyperus ligularis), the vine Cassytha filiformis, and a number of flowering plants, including Launaea intybacea, L. sarmentosa, Ipomoea pes-caprae, Boerhavia repens, Pleurostelma cernuum, Passiflora suberosa, Euphorbia sp., Sida parvifolia, Evolvulus alsinoides, Hypoestes aldabrensis, Cleome strigosa and Asparagus umbellulatus.

At and near the settlement other species are found. These include cultivated trees Moringa oleifera, Terminalia catappa and Carica papaya, decoratives such as Pedilanthus tithymaloides, Catharanthus roseus and Solanum melongena, and a number of other introductions, such as Agave, Gossypium hirsutum, Ricinus communis and Panicum maximum. Maize is also cultivated.

The sand dune vegetation varies with the age and stability of the dune. The active southern dunes are covered with clumps of the sedges Fimbristylis cymosa and Cyperus ligularis, and patches of the grass Dactyloctenium aegyptium. On the lower dunes there is a mosaic of the shrubs Scaevola, Tournefortia and Suriana; two trees of Pisonia grandis nestle in the lee of the southernmost dune, as they do in the lee of Dune Jean-Louis on Aldabra. The northern dunes are most subdued and closely vegetated, with an open woodland of Casuarina, scattered shrubby growths of Colubrina asiatica and Turnera ulmifolia, and a surface cover with much Fimbristylis, together with Eragrostis sp., Dactyloctenium aegyptium, Crotalaria laburnoides and Achyranthes aspera.

The lagoon sand beach, where not directly colonised by mangrove, is a narrow ledge with low Scaevola, Tournefortia and Suriana, with such plants as Tribulus cistoides and Portulaca oleracea. At the north end Sesuvium portulacastrum forms a thick mat between the beach proper and the mangrove zone.

The mangrove vegetation has not been examined in detail. At the north end it consists of mature Avicennia marina and Rhizophora mucronata 10-15 m tall; at the south end of an outer zone of Avicennia, much of it dying, apparently because of the burial of pneumatophores by sediment, together with Rhizophora and Sonneratia alba. Bruguiera gymnorhiza and Ceriops tagal are found in open inlets south of the settlement, lagoonward of the raised reefrock.

The champignon zone was crossed north of the settlement, where it is not very deeply dissected. Euphorbia abbotti was not seen, though previously reported from the atoll. The vegetation of shrubs (Pemphis acidula, Sideroxylon inerme) and a tree (Ficus thonningii) is 2-3 m high. Sarcostemma viminale is abundant (but curiously not Plumbago aphylla, also previously recorded), together with the low, spreading woody shrub Salvadora angustifolia.

Wizard Island

Less is known of the vegetation of Wizard than of Menai. The seaward beach has a scrub of Scaevola and Suriana, with a ground cover of Sporobolus virginicus, Launaea sp., and Euphorbia sp. The dunes have a dense growth of Tournefortia argentea, 1-2 m tall with about 30 per cent dead wood, and Suriana maritima. Sporobolus is not common on the dunes, where the ground cover consists of clumps of Fimbristylis, rosettes of Eragrostis, and Boerhavia.

Between the seaward dunes and the lagoon coast there is a meadow of Dactyloctenium 0.5 m thick, extending up to a line of Agave at the foot of the dunes. This central plain also includes Ipomoea, Achyranthes, Boerhavia, Microstephanus, Plumbago aphylla, Solanum nigrum, species of Portulaca, Sporobolus virginicus, Cassytha, Cassia occidentalis, and a very few dwarf Sideroxylon and Premna. Near the lagoon beach, there is a belt of tall scrub, which is less diverse than similar communities on Aldabra. It includes Acalypha, Azima, Achyranthes, Thespesia populneoides, Allophylus, and Ipomoea pes-caprae. The first three of these species tend to be locally dominant, the Azima reaching up to 3 m in height. Achyranthes is the commonest species, often forming pure stands in which Blue-faced Boobies nest, and in places extending up to the top of the lagoon shore dunes. Vines of Ipomoea tuba drape many of the shrubs.

South of the tall scrub is an area of extremely uneven champignon. The vegetation is dominated by Pemphis, with Ipomoea tuba and Cassytha. Other species noted include Phyllanthus, Acalypha, Achyranthes and Abutilon. Red-footed Boobies nest in this champignon scrub, which appears to be very little disturbed by human activities.

A coastal woodland on the lagoon shore includes moderate-sized mangroves, mostly *Avicennia* but also *Xylocarpus*. Other trees include *Pisonia*, *Abutilon*, *Cordia*, and the shrubs *Suriana* and *Pemphis*.

Fauna other than Birds

Little is known of the marine fauna of Cosmoledo, though it is probably similar in composition and zonation to that of Aldabra. Marine animals were collected in the boulder zone at the edge of the reef flat immediately south of Menai settlement, on a small cliffed promontory close to the village, and to the south of it. In the first area the fauna was rather limited, and hermit crabs were the most conspicuous animals, although on the edge of the reef flat the fauna resembled the inshore fauna under boulders at West Island settlement, Aldabra. The champignon promontory rose steeply, and while not heavily pinnacled, had rock pools nearly 1 m in diameter. The fauna resembled the spray-zone fauna on the top of cliffs on the south coast of Aldabra, and included *Nerita textilis*, *Littorina*, *Crassostrea cucullata*, and several species of grapsid crabs. From this promontory southwards the cliffs are colonised by chitons, dorid nudibranchs, barnacles and small prosobranchs. The reef flat is covered with marine angiosperms, and coral growth on the edge is not luxuriant. Animals noted on the lagoon beach at Wizard include *Grapsus tenuicrustatus*, *Ocypode ceratopthalma*, *Coenobita perlatus*, *C. rugosa* and *Acanthopleura brevispinosa*. Table 5 lists marine mollusca collected on Cosmoledo by P. Grubb in 1968 and identified by J. D. Taylor, and Table 6 Decapod Crustacea, also collected by Grubb and identified by Taylor; both collections are now in the British Museum (Natural History).

Turtles nest on Cosmoledo. On Wizard, the central part of the seaward beach, for a distance of about 100 m, is riddled with at least 50 turtle pits, though there was no sign of turtle activity on the lagoon beach. There is a turtle pen on Menai north of the settlement. Before the August 1968 Green Turtle Protection legislation, at least two Green Turtle were taken each month for food, according to the Manager, and Hawksbill were taken for export.

The terrestrial fauna, so far as is known, is a small one. Land mollusca are represented by two (possibly three) species collected by Thomasset (Connolly 1925). Land crustacea, apart from some of the species listed in Table 6, include *Birgus latro*, reported by Honegger (no date) on Wizard, Grand Polyte and South Islands, and *Cardisoma carnifex*. The reptile fauna formerly included the Giant Land Tortoise *Geochelone gigantea*. The date of its extinction is not known, nor do we know of any historical account of it still living, but Fryer (1911) reports finding fossil eggs in the champignon. There are three other reptiles (Boulenger 1911). *Ablepharus boutonii* has been recorded from Wizard and Menai; none were seen on Menai in 1968, though it was common on Wizard. *Hemidactylus mercatorius* occurs on both islands, and was seen on Menai in 1968. *Phelsuma abbotti* was seen in 1968 on

Table 5. Mollusca collected on Cosmoledo Atoll, 1968

Gastropoda

- Monodonta australis Lamarck
- Turbo marmoratus
- Phasianella aethiopica Philippi
- Nerita albicilla Linnaeus
- N. plicata Linnaeus
- N. textilis Dillwyn
- Littorina undulata Gray
- Cerithium echinatum Lamarck
- Hipponyx conica Schumacher
- Lambis lambis (Linnaeus)
- Strombus gibberulus Linnaeus
- S. mutabilis (Swainson)
- Cypraea arabica Linnaeus
- C. caputserpentis Linnaeus
- C. carneola Linnaeus
- C. caputdraconis Melvill
- C. helvolis Linnaeus
- C. histrio Gmelin
- C. lynx Linnaeus
- C. moneta Linnaeus
- C. tigris Linnaeus
- C. vitellus
- Cymatium nicobaricum (Röding)
- C. pileare (Linnaeus)
- Drupa ricinus (Linnaeus)
- Morula granulata (Duclos)
- M. uva Röding
- Thais aculeata Deshayes
- T. hippocastanum (Linnaeus)
- T. tuberosa (Röding)
- Engina mendicaria (Linnaeus)
- Cantharus undosus (Linnaeus)
- Chrysame fraga (Quoy and Giamard)
- Strigatella acuminata (Swainson)
- S. litterata (Lamarck)
- S. paupercula (Linnaeus)
- Imbricaria filum (Wood)
- Oliva episcopalis Lamarck
- Vasum turbinellus (Linnaeus)
- Conus arenatus Hwass
- C. chaldeus Röding
- C. ebraeus Linnaeus
- C. flavians Lamarck
- C. musicus Hwass
- C. tessulatus Born
- Terebra affinis Gray
- T. cerithina Lamarck

Amphineura

- Acanthopleura brevispinosa (Sowerby)

Bivalvia

- Isognomon dentifer (Krauss)
- Donax faba (Gemlin)

Collected by P. Grubb; identified by J. D. Taylor; incorporated into the collections of the British Museum (Natural History), accession number 2213. All species were collected on the beach of Menai Island.

Table 6. Crustacea (Decapoda) collected on Cosmoledo Atoll, 1968

Wizard Island

- Ocypode ceratopthalma (Pallas): 1♂

Menai Island

- Grapsus tenuicrustatus (Herbst): 2♂, 2♀
- Geograpsus stormi (de Man): 1♂
- Eriphia laeuimana (Guerin): 1♂
- Epixanthus frontalis (Milne Edwards): 3♂
- Leptodius quinquedentatus (Krauss): 4♂
- Petrolisthes lamarckii (Leach)
- Pagurus pedunculatus (Herbst)
- Clibanarius striolatus (Dana)
- Calcinus laevimanus (Randall)
- Coenobita rugosus (Milne Edwards)

Collected by P. Grubb; identified by J. D. Taylor; incorporated into the collections of the British Museum (Natural History).

Menai but not on Wizard; it is more brightly coloured than the Aldabra Phelsuma. Honegger (1966) distinguished P. abbotti menaiensis on Menai and P. abbotti subsp. on Wizard, Grand Polyte and South Island.

Insects were collected on Cosmoledo by Fryer in 1908, and forty species are recorded in the Percy Sladen Expedition Reports; these records are keyed in Table 7. Of these, only two species were Lepidoptera. Legrand's (1965) collections of Lepidoptera on Menai totalled 70 species, including 1 new genus, 24 new species, and 3 new subspecies, mostly Microlepidoptera, though some of these may need revision. B. H. Cogan and A. Hutson made a transect of Wizard Island in March 1968, collecting insects on a transect at the narrowest point between lagoon and seaward shore. Insects were abundant in number if not in variety, but unlike Astove only the smaller species appeared to be well represented. Many of the larger species were apparently scarce, perhaps as a result of the lack of permanent fresh water. Acridid grasshoppers were present in some numbers, and females of the large Cyrtacanthacris tatarica tatarica L. were common. Butterflies and Odonata were nowhere common, and the small Lycaenid Syntarucus pirithous L. was the only species to be seen in any number. The morning visit to Wizard was followed in the afternoon by 3-4 hours on Menai, but because of rain the collections were totally unrepresentative of the fauna there. The only insect of note recognised in the collections so far is a species of Pipunculid fly, the first record of this interesting parasitic family of Diptera in the Aldabra group. Most of Legrand's collecting was carried out on Menai, and the 1968 collections may be the first on Wizard. Cosmoledo has a small faunal element that it shares with Astove and none of the other islands in the

Table 7. Insects recorded from Cosmoledo Atoll by the Percy Sladen Expedition

Group	Number of species	Reference
Orthoptera	11	Bolivar (1912, 1924)
Dermaptera	1	Burr (1910)
Hemiptera	8	Distant (1913)
Lepidoptera	2	Fryer (1912)
Coleoptera	11	Champion (1914), Gebien (1922), Schenkling (1922), Scott (1912, 1926), Sicard (1912)
Hymenoptera	5	Cockerell (1912), Turner (1911)
Diptera	1	Lamb (1922)
Odonata	1	Campion (1913), Blackman and Pinhey (1967)

group, for example a Dolichopodid fly genus Sciapus sp. n. and a Trypetid fruit fly Coelotrypes vittatus. The majority of species, however, found on Cosmoledo are found throughout the Aldabra group of islands.

Birds

The bird fauna of Cosmoledo is smaller than that of Aldabra and has attracted little attention. Earlier treatments are those of Fryer (1911), Vesey-FitzGerald (1940, 1941), Hartman (1958), Bourne (1966), and Watson and others (1963). Benson (1970a) deals in detail with the land and shore birds in the following chapter, drawing on the earlier literature and on collections and observations made during the Royal Society visits and from that by I. S. C. Parker.

Of the seven recorded land birds, only two are common: Cisticola cherina, which Benson believes to be native and not introduced, and, less abundant, Nectarinia sovimanga. Hartman (1958) reported Zosterops maderaspatana to be common on Menai; the March 1968 party did not see it at all, though Stoddart and Poore saw it on Menai in September. Two land birds are probably extinct, the flightless Rail Dryolimnas cuvieri and the Turtledove Streptopelia picturata. Abbott (in Ridgway 1895) and Fryer (1911) both reported the existence of a rail on Cosmoledo, the latter specifying South Island, though he did not land there and observe it. It is possible but very doubtful that both Dryolimnas and Streptopelia both still survive on South Island. Two other land birds are recorded: Geopelia striata was seen briefly by Benson, and there are a few crows Corvus albus. Possible resident shore birds, all seen in 1968, are Ardea cinerea, Egretta garzetta, Bubulcus ibis, and Butorides striatus. Benson (1970a) lists a dozen migrants recorded from the atoll. This paucity in species (seven true land birds at most, plus four possibly resident shore birds) contrasts with the eighteen species of land birds recorded for Aldabra. Endemism is also low, though Benson (1970b) has discussed a well-marked subspecies of Nectarinia sovimanga, only otherwise known on Astove.

Sea birds have been briefly noticed by several previous workers, notably Dupont (1907), Vesey-FitzGerald (1941), Honegger (unpublished), Gaymer (unpublished), and observers on H.M.S. Owen in 1964 (Bourne 1966). Diamond visited Wizard in the morning and Menai in the afternoon of 6 March 1968. Three species nest in large numbers on Wizard: Sula dactylatra, Sula sula and Sterna fuscata. At least 200 pairs of White Booby S. dactylatra were occupying clearings in the long grass on the west side of the island or on the dune ridge to the east. Most were displaying at empty nest sites or in apparently inactive attendance at past sites. Only five occupied nests were found, four with single eggs and the other with two. There were also two fully-feathered juveniles, both of which regurgitated large flying-fish (probably Cypsilurus sp.). On Ascension Island in the Atlantic, Dorward (1962) found that territories of this species were defended outside the breeding season, and that

although eggs were laid in most months of the year there was a marked peak of laying in one or two months. He found the incubation period to be 42-46 days, and fledging to take about 120 days; so that the near-fledged chicks found on Wizard in March would have come from eggs laid in the previous October. The eggs found would have been laid in the previous six weeks, and there were no younger chicks; hence, as the great majority of the birds had neither eggs nor young, the main laying period must be between March and October. Vesey-FitzGerald (1941) describes this species as breeding on four islands of the atoll (West North, East North, Grand Polyte, South) but not on Wizard, presumably during his visit between September and November 1937.

Towards the south end of Wizard, low bushes appear among the long grass and finally merge into dense clumps 2-3 m high, covered with thorny creepers and penetrable only with the greatest difficulty. These bushes were occupied by nesting Red-footed Boobies _Sula sula_, whose numbers were impossible to estimate with any accuracy but which were well in excess of 150 pairs. On the lagoon shore at least 20 pairs were nesting in a small clump of _Avicennia_ mangrove, which on Aldabra is avoided as a nesting site. Those nests whose contents could be seen either contained eggs or were empty, while on Aldabra, and on Menai Island on Cosmoledo, most nests contained eggs or half-grown chicks. All the adults seen were of the white phase.

Along the dune ridge, and in clearings in the long grass to the north of the landing place on the lagoon shore, many fragmented skeletons and feathers of the Sooty Tern _Sterna fuscata_ were found; Vesey-FitzGerald (1941) describes this species as nesting on Wizard. They clearly suffer heavy mortality, similar to that on Goelette Island, Farquhar Atoll (Stoddart and Poore 1970); whether this is from predation, starvation or disease on Cosmoledo is not known, but the most likely culprits would seem to be cats, of which two were seen and one shot, and which cause serious losses to Sooty Terns on Ascension Island (Ashmole 1963). Baker (1963) refers to a tern-breeding area at the north end of Wizard, and though no living Sooty Terns were seen on the island they were heard and seen over the ships at night, and a few were seen between Astove and Cosmoledo early on 5 March.

The other sea birds seen on Wizard were three Red-tailed and two Yellow-billed Tropicbirds _Phaethon rubricauda_ and _P. lepturus_; two Black-naped Terns _Sterna sumatrana_; and a single female Great Frigate Bird _Fregata minor_. Honegger (unpublished) reported that _P. rubricauda_ nests on Cosmoledo in March.

Diamond also covered the northern half of Menai Island, from the settlement round to the lagoon shore mangroves. Red-footed Boobies, many with half-grown chicks, were nesting in the mangroves, particularly the tall _Rhizophora_ on the landward fringe. A few Frigate birds _Fregata_ sp. were seen soaring over tall mangroves on Chauve-souris island; the only Frigate bird certainly identified on the atoll was a female Great Frigate bird _Fregata minor_ harrying White Boobies on Wizard. At dusk there was a large flight of Red-footed Boobies in from the sea, flying

low and fast over the dunes and usually avoiding the attention of the few Frigate birds soaring in wait.

Stoddart and Poore noted soaring Frigates over the south end of Menai in September 1968, and large numbers of boobies on an island to the south of Menai. Piggott (1961) mentions large numbers of boobies on Grand Polyte, and also bird colonies on Pagoda and South Island, all of which need investigation.

The following list summarises the records of sea birds on Cosmoledo; for similar lists of the land and shore birds, see the accompanying paper by Benson (1970a).

Puffinus l'herminieri

Heard at night over the settlement on Menai; reported by local fishermen to Diamond.

Phaethon rubricauda

Said to breed by Vesey-FitzGerald (1941) and reported by Honegger (unpublished) on the nest in March. H.M.S. *Owen* reported this species over Menai (Bourne 1966), and Diamond saw three on Wizard.

Phaethon lepturus

Sight record by R. D. T. Gaymer on 1 October 1965; two seen by Diamond on Wizard.

Sula dactylatra

Reported breeding by Vesey-FitzGerald (1941) on West North, East North, Polyte and South Islands, and by Diamond on Wizard. Also recorded by H.M.S. *Owen* (Bourne 1966).

Sula sula

Reported by Vesey-FitzGerald (1941) on Menai, East North, Grand Polyte, Wizard and South Islands. Reported by Honegger (unpublished) breeding in trees on Grand Polyte, by Diamond in mangroves on Menai, and by Stoddart and Poore on island south of Menai. Gaymer (unpublished) found a large colony with many young, 1 October 1965, on Chauve-souris, 200 per annum reportedly being taken for food. Recorded by H.M.S. *Owen* in March (Bourne 1966); collected by Parker in September.

Sula leucogaster

Reported by locals to Diamond as breeding. Collected by Parker, 5 October 1967.

Fregata ariel

Reported by locals to Diamond as breeding. Said to breed on islets by Vesey-FitzGerald (1941).

Fregata minor

Diamond identified one female on Wizard; locally reported to breed. Said to breed on islets by Vesey-FitzGerald (1941).

Hydroprogne caspia
Sight, Vesey-FitzGerald (1941).

Sterna anaethetus
On islets in October (Vesey-FitzGerald 1941).

Sterna fuscata
Breeds on Wizard Island (Vesey-FitzGerald 1941; Diamond, this paper).

Sterna albifrons

Sterna sumatrana
2 seen by Diamond on Wizard, 1968.

Thalasseus bergii
Sight record by Gaymer, 1 October 1965.

Anous stolidus
Breeding on islets, according to Vesey-FitzGerald (1941).

Settlement

Little is known of the history of settlement on Cosmoledo. It is more hospitable than Aldabra and presumably more attractive to early sailors, though permanent settlement may have been hindered by lack of fresh water. Moresby (1822, 30) reported that "the Cosmoledo Isles are sometimes resorted to for fish, where a few blacks are left, who wait the vessels return". The atoll was settled by the time of a visit by Sebert Baty in 1895 (Bergne 1900). Two to three hundred coconuts had been planted, maize grew fairly well, and goats thrived in numbers. There was at that time a reservoir on Menai holding 1300 velts (1950 gallons) of water, and one iron roof for catchment, together with one roof and 500 velts (750 gallons) capacity on Wizard. There was also on Menai a "large iron pan in which one man is able to distill 6 velts (9 gallons) of water a day including wood cutting and carrying". It was said that the atoll could provide work for twelve labourers. When H. A'C. Bergne visited it in 1901 there were two men on Menai, though seventeen were left there in the season: nine to take turtle, six for fishing, and two for preparing fish and shell. James Spurs was in charge of the atoll, which had two pirogues, a corrugated iron house, and labourers' huts made from piled-up turtle carapaces. Bergne (1901) found that half a dozen goats on Menai were not doing well, in contrast to the rats. In a good season 5000 lb of maize could be produced, but there were frequent failures of the harvest. In addition to the 2 persons on Menai, there was one on Wizard, though no plantation, and four on Northeast. The exploitation of guano had already begun on Northeast Island: Bergne stated that 120 tons had already been removed, at Rs 60 per ton, and that 300-400 tons were left.

The only island now inhabited is Menai, where there is a settlement with water tanks, a manager's house, labourers' houses and a small cemetery. There are fishing huts on Wizard and some of the other islands.

Guano is no longer worked on Northeast Island, though several hundred tons remain in cavities; Baker (1963) also estimates reserves on Grand Polyte, not yet worked, at 3700 tons.

The goats formerly reported on Menai are no longer there, but are reported by Piggott (1961) for Northeast Island. Rabbits have been introduced on South Island, according to Dupont (1907) before 1906, though according to Honegger (unpublished) about 1930. Two cats were seen on Wizard in 1968.

Until 1903, when it was transferred to the new colony of Seychelles, Cosmoledo was administered as part of Mauritius: it still forms part of Seychelles, and was not included in the British Indian Ocean Territory in 1965. The atoll is now leased, with Aldabra and Assumption, by Mr H. Savy of Mahé, and is used primarily as a fishing station. There are few coconuts, and Piggott (1961) reported the average yield to be only two nuts per palm per annum.

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6. PLANTS OF COSMOLEDO ATOLL

F. R. Fosberg and S. A. Renvoize

CYMODOCEA CILIATA Ehrenb. ex Aschers.
Menai I., south part, Fosberg 49854 (US, K).

HALODULE WRIGHTII Aschers.
Menai I., south part, Fosberg 49851 (US, K).

THALASSIA HEMPRICHII (Ehrenb.) Aschers.
Menai I., south part, Fosberg 49852, 49853 (US, K).

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
Menai I., s. l., Gwynne & Wood 1263 (K, EA); south of Settlement, Stoddart & Poore 1228 (K); north of Settlement, Stoddart & Poore 1254 (K); Wizard I., central part, Fosberg 49794 (US, K); Renvoize 1264 (US, K).

DACTYLOCTENIUM PILOSUM Stapf
Wizard I., central part, Fosberg 49800 (US, K), Renvoize 1262 (US, K); north end, Fosberg & McKenzie 49828 (US).

DAKNOPHOLIS BOIVINII (Camus) Clayt.
Wizard I., central part, Fosberg 49805 (US, K); Renvoize 1263 (US, K); Menai I., s. l., Gwynne & Wood 1237 (K, EA).

DIGITARIA HORIZONTALIS Willd.
Menai I., s. l., Gwynne & Wood 1238 (K, EA); north end, Fosberg 49786 (US, K).

ENTEROPOGON SECHELLENSIS Dur. & Schinz
Wizard I., central part, Fosberg 49814 (US, K); Renvoize 1265 (US, K).

ERAGROSTIS sp.
Wizard I., Fosberg 49813a (US); north end, Fosberg 49830 (US, K); central part, Renvoize 1261 (US, K); Menai I., south of Settlement, Stoddart & Poore 1224 (K); north of Settlement, Stoddart & Poore 1260 (K); south part, Fosberg 49849 (US, K).

LEPTURUS REPENS R. Br.
Menai I., s. l., Gwynne & Wood 1249 (EA); north end, Fosberg & McKenzie 49789 (US); north of Settlement, Stoddart & Poore 1261 (K, US); Renvoize 1240 (US, K), Renvoize 1252 (US,K).

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PANICUM MAXIMUM Jacq.
Menai I., s. l., Fosberg 49776 (US); south of Settlement, Stoddart & Poore 1221 (K, US); north end, Fosberg & Grubb 49776 (US).

PANICUM VOELTZKOWII Mez
Wizard I., near south end, Fosberg & Grubb 49819 (US, K); north end, Fosberg & McKenzie 49827 (US, K).

SPOROBOLUS VIRGINICUS Kunth
Wizard I., near south end, Fosberg & Grubb 49825a (US).

STENOTAPHRUM MICRANTHUM (Desv.) Hubb.
Menai I., Fosberg 49783 (US); north of Settlement, Renvoize 1241 (US, K).

ZEA MAYS L.
Menai I., north of Settlement, Renvoize 1251 (US, K).

CYPERUS LIGULARIS L.
Menai I., south of Settlement, Stoddart & Poore 1227 (K); south part, Fosberg 49838 (US, K).

FIMBRISTYLIS CYMOSA R. Br.
Wizard I., central part, Fosberg 49806b (US); Menai I., south of Settlement, Stoddart & Poore 1235 (K, US).

COCOS NUCIFERA L.
Menai I., seen by Stoddart, 1967, and by Fosberg, 1968; north of Settlement, Renvoize 1254 (US, K).

AGAVE SISALANA Perr.
Wizard and Menai I., seen by Fosberg, 1968. Menai I., Renvoize s. n.. March 1968, spirit collection only (K, US).

ASPARAGUS UMBELLULATUS Sieb.
Menai I., s. l., Gwynne & Wood 1265 (K, EA); north end, Fosberg & Grubb 49774 (US); south of Settlement, Stoddart & Poore 1207 (K); north of Settlement, Renvoize 1237 (US, K).

LOMATOPHYLLUM BORBONICUM Willd.
Reported by Hemsley (1919) on authority of Dupont, no specimen seen by Hemsley.

CASUARINA EQUISETIFOLIA L.
"Dupont records this from all islands [in the Aldabra Group]", Hemsley (1919); seen by Stoddart, 1967, and by Fosberg on Menai I., 1968.

FICUS AVI-AVI Bl.
Menai I., north of Settlement, Renvoize 1249 (US, K).

FICUS NAUTARUM Baker

"Dupont records this species from all of the islands [in Aldabra group]", Hemsley (1919).

FICUS THONNINGII Bl.

"Dupont records this species from ... Cosmoledo ..." Hemsley (1919); Menai I., north of Settlement, Stoddart & Poore 1257 (K); Gwynne & Wood 1241 (EA); north end, Fosberg & Grubb 49765 (US, K), 49768 (US, K).

BOERHAVIA DIFFUSA L.

Menai I., Gwynne & Wood 1258 (EA).

BOERHAVIA ELEGANS Choisy

Wizard I., s. l., Thomasset in 1902 (K); central part, Renvoize 1226 (US, K).

BOERHAVIA REPENS L.

Wizard I., central part, Fosberg 49792 (US, K), 49806 (US, K); Menai I., south part of Settlement, Stoddart & Poore 1240 (K, US).

PISONIA GRANDIS R. Br.

Wizard I., central part, Fosberg 49807 (US, K); Menai I., south of Settlement, Stoddart & Poore 1241 (K).

ACHYRANTHES ASPERA L.

Wizard I., s. l., Gwynne & Wood 1224 (EA); central part, Renvoize 1219 (US, K); Menai I., north of Settlement, Stoddart & Poore 1249 (K); central part, Fosberg 49748 (US, K); south part, Fosberg 49850 (US, K).

ACHYRANTHES CANESCENS R. Br.

E. North I., Vesey-FitzGerald 5990 (K); Wizard I., Thomasset in 1902 (K).

SESUVIUM PORTULACASTRUM L.

Menai I., Gwynne & Wood 1266 (EA).

PORTULACA cf. AUSTRALIS Endl.

S. l., Thomasset 214 (K); Wizard I., near south end, Fosberg & Grubb 49823 (US, K); Renvoize 1260 (US, K); Renvoize 1221 (US, K).

PORTULACA OLERACEA L.

Wizard I., s. l., Gwynne & Wood 1223 (EA); central part, Fosberg 49802 (US, K); Menai I., north of Settlement, Stoddart & Poore 1245 (K).

CASSYTHA FILIFORMIS L.

Wizard I., near south end, Fosberg & Grubb 49818 (US); Menai I., south of Settlement, Stoddart & Poore 1233 (K); north of Settlement, Renvoize 1246 (US, K).

CLEOME STRIGOSA (Boj.) Oliv.
Wizard I., s. l., Thomasset in 1902 (K); central part, Fosberg 49796 (US, K); Renvoize 1229 (US, K); Menai I., s. l., Gwynne & Wood 1251 (K, EA); south of Settlement, Stoddart & Poore 1216 (K).

MORINGA OLEIFERA Lam.
Menai I., north end, Fosberg & Graham 49782 (US, K); south of Settlement, Stoddart & Poore 1218 (K).

CAESALPINIA BONDUC (L.) Roxb. ?
Menai I., Gwynne & Wood 1248 (EA).

CAESALPINIA MAJOR (Medic.) Dandy & Exell
Menai I., south of Settlement, Stoddart & Poore 1211 (K).

CASSIA OCCIDENTALIS L.
Menai I., south of Settlement, Stoddart & Poore 1200 (US, K, EA); Wizard I., central part, Renvoize 1220 (US, K).

CROTALARIA LABURNOIDES Klotzsch
Menai I., north of Settlement, Stoddart & Poore 1250 (K, US).

GAGNEBINA PTEROCARPA (Lam.) Baill.
"'Very common and also in Cosmoledo'--Thomasset" Hemsley (1919).

ERYTHROXYLON ACRANTHUM Hemsl.
Menai I., Gwynne & Wood 1233 (K, EA); north end Fosberg & Grubb 49771 (US, K).

TRIBULUS CISTOIDES L.
Wizard I., s. l., Thomasset in 1903 (K); central part Renvoize 1225 (US, K); Menai I., north of Settlement, Stoddart & Poore 1248 (K).

SURIANA MARITIMA L.
Wizard I., central part, Renvoize 1231 (US, K); Menai I., Vesey-FitzGerald 5986a (K); south of Settlement, Stoddart & Poore 1238 (K).

XYLOCARPUS MOLUCCENSIS (Lam.) Roem.
Wizard I., near south end, Fosberg & Grubb 49820 (US, K); Renvoize 1266 (K).

ACALYPHA CLAOXYLOIDES Hutch.
S. l., Thomasset 243 (K); Menai I., s. l., Gwynne & Wood 1240 (K, EA); south of Settlement, Stoddart & Poore 1231 (K); E. North Is., Vesey-FitzGerald 5989 (K); Wizard I., central part, Fosberg 49804 (US, K, Fo).

ACALYPHA INDICA L.
Menai I., Fosberg 49844 (US, K).

EUPHORBIA ABBOTTII Baker

"Dupont records this from all the islands of the Seychelles region except Gloriosa, but not from the Seychelles Archipelago" Hemsley (1919); s. l., Fryer 52 (K); Menai I., north end, Fosberg & Grubb 49764 (US, K).

EUPHORBIA HIRTA L.

Menai I., south part, Fosberg 49848 (K, US).

EUPHORBIA sp. (near E. PROSTRATA Ait.)

S. l., Thomasset 232 (K); Wizard I., s. l., Gwynne & Wood 1230 (K, EA); near south end, Fosberg & Grubb 49816 (US, K); central part, Fosberg 49799 (US, K); dunes in center, Fosberg 49806a (US, K); central part, Renvoize 1228 (US, K); Menai I., south of Settlement, Stoddart & Poore 1222 (K).

PEDILANTHUS TITHYMALOIDES (L.) Poit.

Menai I., south of Settlement, Stoddart & Poore 1214 (K), 1202 (US, K, EA).

PHYLLANTHUS AMARUS Schum. & Thonn.

Wizard I., north end, Fosberg & McKenzie 49826 (US); central part, Renvoize 1222 (US, K).

PHYLLANTHUS CHELONIPHORBE Hutchinson

Menai I., north end, Fosberg & Graham 49788 (US); Renvoize 1242 (US, K).

PHYLLANTHUS sp.

Wizard I., north end, Fosberg & McKenzie 49831, 49826 (US); near south end, Fosberg & Grubb 49815a (US).

RICINUS COMMUNIS L.

Menai I., north end, Fosberg & Grubb 49775 (US).

MAYTENUS SENEGALENSIS (Lam.) Exell

Menai I., north end, Fosberg & Grubb 49781 (US); north of Settlement, Renvoize 1245 (US, K).

ALLOPHYLUS ALDABRICUS Radlk.

Menai I., south of Settlement, Stoddart & Poore 1205 (K, US); north end, Fosberg & Grubb 49770 (US, K); north of Settlement, Renvoize 1248 (US, K).

COLUBRINA ASIATICA (L.) Brongn.

Wizard I., central part, Fosberg 49811 (US, K); Renvoize 1257 (US, K); Menai I., s. l., Gwynne & Wood 1262 (K, EA), 1256 (EA); north of Settlement, Stoddart & Poore 1246 (K).

GOUANIA TILIAEFOLIA Lam.

Wizard I., s. l., Thomasset in 1903 (K).

SCUTIA MYRTINA (Burm. f.) Kurz
Menai I., s. l., Gwynne & Wood 1244 (EA); Fosberg & Grubb 49773 (US).

CORCHORUS AESTUANS L.
Wizard I., central part, Fosberg 49810 (US, K); Renvoize 1234 (US, K).

GREWIA SALICIFOLIA Schinz
Menai I., s. l., Gwynne & Wood 1257 (K, EA); north of Settlement, Renvoize 1239 (US, K); south of Settlement, Stoddart & Poore 1212 (K); north end, Fosberg & Grubb 49763 (US, K).

ABUTILON ANGULATUM (G. & P.) Mast.
S. l., Thomasset 226 (K); Wizard I., central part, Fosberg 49803 (US, K).

GOSSYPIUM HIRSUTUM L.
Wizard I., s. l., Gwynne & Wood 1226 (K, EA); central part, Fosberg 49812 (US, K); Renvoize 1233 (US, K); Menai I., south of Settlement, Stoddart & Poore 1220 (K).

SIDA PARVIFOLIA DC.
S. l., Stoddart & Poore 1217 (K); Wizard I., near south end, Fosberg & Grubb 49815 (US, K); central part, Renvoize 1235 (US, K); Menai I., south of Settlement, Stoddart & Poore 1230 (K).

SIDA "VESCOANA Baillon"
Wizard I., s. l., Thomasset in 1902 (K), (possibly a form of *S. parvifolia* DC.).

THESPESIA POPULNEOIDES (Roxb.) Kostel.
Menai I., north end, Fosberg & Grubb 49766 (US); Renvoize 1238 (US, K).

TURNERA ULMIFOLIA L.
Menai I., north of Settlement, Stoddart & Poore 1247 (K).

PASSIFLORA SUBEROSA L.
Menai I., south of Settlement, Stoddart & Poore 1208 (K).

CARICA PAPAYA L.
Seen on Menai I. by Stoddart, 1967.

CUCUMIS MELO L.
Menai I., s. l, Gwynne & Wood 1255 (EA); Wizard I., central part, Fosberg 49797; Renvoize 1224 (US, K); Renvoize 1267 (K).

CUCURBITA MAXIMA L.
Menai I., north end, Fosberg 49787 (US).

PEMPHIS ACIDULA Forst.
S. l., Thomasset 217 (K); FitzGerald 5988 (K); Menai I., south of Settlement, Stoddart & Poore 1242 (K); Wizard I., central part, Renvoize 1230 (US, K).

BRUGUIERA GYMNORHIZA (L.) Lam.
Menai I., s. l., Gwynne & Wood 1259 (K, EA); south of Settlement, Stoddart and Poore 1209 (K, US).

CERIOPS TAGAL (Perr.) C. B. Rob.
Menai I., south of Settlement, Stoddart & Poore 1210 (K, US).

RHIZOPHORA MUCRONATA Lam.
Menai I., s. l., Gwynne & Wood 1261 (K, EA); south of Settlement, Stoddart & Poore 1239 (K).

SONNERATIA ALBA (L.) J. E. Sm.
Menai I., lagoon side, south of Settlement, Stoddart & Poore 1223 (K).

TERMINALIA CATAPPA L.
Menai I., south of Settlement, Stoddart & Poore 1213 (K).

AZIMA TETRACANTHA Lam.
Wizard I., central part, Fosberg 49808 (US, K); Menai I., s. l., Gwynne & Wood 1243 (EA); south of Settlement, Stoddart & Poore 1237 (K); north end, Fosberg & Grubb 49779 (US, K).

SALVADORA ANGUSTIFOLIA Turr.
S. l., Dupont 289 (K), 5 (K); Menai I., s. l., Gwynne & Wood 1247 (K, EA), 1242 (EA); north of Settlement, Stoddart & Poore 1258 (K); Renvoize 1243 (US, K); north end, Fosberg 49784 (US, K), 49785 (US).

PLUMBAGO APHYLLA Boj. ex Boiss.
Wizard I., s. l., Gwynne & Wood 1227 (EA); central part Fosberg 49809 (US, K); Renvoize 1232 (US, K).

SIDEROXYLON INERME L. subsp. CRYPTOPHLEBIUM (Baker) J. H. Hemsley
Wizard I., central part, Fosberg 49813 (US, K); Menai I., north end, Fosberg & Graham 49782a (US); north of Settlement, Stoddart & Poore 1255 (K), 1256 (K).

CATHARANTHUS ROSEUS (L.) G. Don
Menai I., south of Settlement, Stoddart & Poore 1215 (K).

PLEUROSTELMA CERNUUM (Decne.) Bullock
Wizard I., central part, Fosberg 49801 (US, K); Renvoize 1227 (US, K); Menai I., s. l., Gwynne & Wood 1234 (K, EA), 1252 (EA); south of Settlement, Stoddart & Poore 1219, 1203, 1204 (K).

SARCOSTEMMA VIMINALE R. Br.

Menai I., s. l., Gwynne & Wood 1239 (EA); north of Settlement, Stoddart & Poore 1253 (K, US); Renvoize 1244 (US, K).

EVOLVULUS ALSINOIDES L.

S. l., Thomasset in 1902 (K); Wizard I., north end, Fosberg & McKenzie 49832 (US); central part, Renvoize 1259 (US, K); south end, Gwynne & Wood 1231 (EA); Menai I., south of settlement, Stoddart & Poore 1229 (K).

IPOMOEA PES-CAPRAE (L.) R. Br.

Wizard I., central part, Fosberg 49790 (US, K); Renvoize 1218 (US, K); Menai I., south of Settlement, Stoddart & Poore 1232 (K).

IPOMOEA TUBA (Schlecht.) Don

Wizard I., central part, Fosberg 49793 (US, K); Renvoize 1223 (US, K).

CORDIA SUBCORDATA Lam.

Wizard I., near south end, Fosberg & Grubb 49821 (US, K); Menai I., south of Settlement, Stoddart & Poore 1236 (K); north end, Fosberg & Grubb 49767 (US).

TOURNEFORTIA ARGENTEA L. f.

Menai I., south of Settlement, Stoddart & Poore 1234 (K); Wizard I., central part, Renvoize 1256 (US, K).

AVICENNIA MARINA (Forsk.) Vierh.

S. l., Fryer 22 (K); Wizard I., near south end, Fosberg & Grubb 49825 (US, K); Menai I., s. l., Gwynne & Wood 1260 (K, EA); north of Settlement, Stoddart & Poore 1259 (K); south of Settlement, Stoddart & Poore 1225 (K).

CLERODENDRUM GLABRUM E. Mey. (C. minutiflorum Bak.)

"Dupont records this from Cosmoledo," Hemsley, (1919); s. l., Thomasset in 1902 (K, 2 sheets).

PREMNA OBTUSIFOLIA R. Br.

Menai I., s. l., Gwynne & Wood 1250 (EA); north end, Fosberg & Grubb 49780 (US, K); north of Settlement, Renvoize 1236 (US, K); south of Settlement, Stoddart & Poore 1206 (K), 1226 (K).

SOLANUM ALDABRENSE C. H. Wright

"Dupont records this from ... Cosmoledo", Hemsley (1919).

SOLANUM MELONGENA L.

Menai I., north of Settlement, Stoddart & Poore 1244 (K).

SOLANUM NIGRUM L.

Wizard I., north end, Fosberg & McKenzie 49829 (US); central part, Renvoize 1258 (US, K).

HYPOESTES ALDABRENSIS Baker

Wizard I., s. l., Gwynne & Wood 1225 (K, EA); near south end, Fosberg & Grubb 49817 (US, K); Menai I., s. l., Gwynne & Wood 1264 (EA); north of Settlement, Stoddart & Poore 1252 (K).

GUETTARDA SPECIOSA L.

Menai I., s. l., Vesey-FitzGerald 5987 (K); north of Settlement, Renvoize 1250 (US, K).

POLYSPHAERIA MULTIFLORA Hiern

Menai I., north end, Fosberg & Grubb 49772 (US).

TARENNA TRICHANTHA (Bak.) Brem.

S. l., Dupont 279 (K).

TRIAINOLEPIS FRYERI (Hemsl.) Brem.

S. l., Thomasset 242 (K).

SCAEVOLA TACCADA (Gaertn.) Roxb.

Wizard I., near south end, Fosberg & Grubb 49824 (US); Menai I., north of Settlement, Renvoize 1253 (US, K).

LAUNAEA INTYBACEA (Jacq.) Beauv.

Menai I., s. l., Gwynne & Wood 1253 (EA); north of Settlement, Stoddart & Poore 1262, 1201 (K, US); Renvoize 1247 (US, K).

LAUNAEA SARMENTOSA (Willd.) Alst.

S. l., Dupont 35 (K); Wizard I., s. l., Gwynne & Wood 1229 (EA); central part, Fosberg 49791 (US, K); Renvoize 1217 (US, K); Menai I., south of Settlement, Stoddart & Poore 1243 (K, US).

VERNONIA ALDABRENSIS Hemsl.

Menai I., north end of Settlement, Stoddart & Poore 1251 (K); north end, Fosberg & Grubb 49777 (US, K).

7. LAND (INCLUDING SHORE) BIRDS OF COSMOLEDO

C. W. Benson

Introduction

Excepting a brief reference by Abbott to a rail (see below), the earliest reference to birds on Cosmoledo seems to be by Bergne (1901), who had the lease of Aldabra, including also Cosmoledo, at the beginning of the century. Dr D. R. Stoddart has brought to my notice the list of birds made by Bergne, as a result of his visit to Cosmoledo between 9 and 12 October 1901. In addition to five sea birds and a "curlew", it includes four species to be referred to below. Dupont (1907) drew up a fairly comprehensive list of birds as a whole. Fryer (1911, 430) thought that land birds were scarce on Cosmoledo, which was "too broken into small islands to be suitable for a land fauna". Vesey-FitzGerald (1940, 486-488) gives an account of the land, exclusive of shore, birds of the Aldabra archipelago, including Cosmoledo, which he visited in 1937. According to Williams (1953) and Benson (1969) he also collected sunbirds and a white-eye on Menai Island in April 1952. But he has recently explained to me that he only visited Cosmoledo the once, in 1937, and that these specimens were merely collected at his request, and that at the time he was in Africa. Hartman (1958), who spent 10-12 December 1957 on Cosmoledo, visiting Menai and West North Islands, also gives an account of the land birds. H.M.S. Owen called at Menai on 13-15 March 1964, and some observations are given by Bourne (1966). The Bristol Seychelles Expedition, of which R. Gaymer was a member, visited Menai on 9 November 1964, and Gaymer made a further visit to Menai on October 1965. He has kindly made his observations available. I. S. C. Parker collected specimens for the National Museum of Kenya, Nairobi, on Menai on 6 October 1967.

A grant from the Frank M. Chapman Memorial Fund, made at the instance of Dr Dean Amadon, Lamont Curator of Birds in the American Museum of Natural History, enabled me to visit Cosmoledo and Astove myself, on the M.F.R.V. Manihine, during the time that I was working on Aldabra, in January-March 1968. We were on Cosmoledo on 6 March: on Wizard Island from about 0900 to 1300 hours, and on Menai Island from 1600 to 1845 hours. My own observations were augmented by many from A. W. Diamond and P. Grubb. Some additional observations were made on Menai Island by Dr M. E. D. Poore and Dr D. R. Stoddart during a further visit by M.F.R.V. Manihine, on 14 September 1968.

In addition to the generous assistance from the Chapman Fund, I am much indebted to various other persons. Dr R. H. Carcasson, the former Director, and A. D. Forbes-Watson, lent me the specimens collected by Parker for the National Museum of Kenya, and permitted me to make use of them in this paper. They also seconded to me a skinner, Loriu Lokiru, who worked for me throughout my time on Aldabra, and accompanied me to Cosmoledo and Astove. Professor Charles G. Sibley and Mrs Eleanor H. Stickney lent me the material collected by Hartman in the Aldabra archipelago as a whole, in the Peabody Museum of Natural History, Yale University, and which was brought to my notice by R. K. Brooke, of Rhodesia, while on a visit to that Museum. A. M. Hutson, of the Department of Entomology, British Museum (Natural History), has identified the stomach contents of my specimens. Dr D. W. Snow and his staff in the Bird Room, British Museum (Natural History), have given me the necessary facilities for the comparative study of specimens. My own from Cosmoledo and Astove are to be presented to the American Museum of Natural History, while Parker's land birds from these two atolls have recently been donated by the National Museum of Kenya to the British Museum (Natural History). I thank Mr J. A'C. Bergne for the opportunity to make use of unpublished observations made by his father on Cosmoledo in 1901.

Resident true land birds

Dryolimnas cuvieri — White-throated Rail

Abbott (in Ridgway 1895, 529) had it at second-hand that rails "swarm" on Cosmoledo (and Astove), while according to Fryer (1911, 430, under *D. abbotti* ?), a rail still existed in 1908 on South Island, Cosmoledo. We were unable to land on South Island, which has no human settlement, so that it is possible that this species does still exist there. This is worth further investigation.

Streptopelia picturata — Malagasy Turtledove

This species is listed by Dupont (1907, as *Turtur saturatus*) for Cosmoledo, and Bergne (1901) mentions a brown "Tourterelle des Iles", but no other reference to its occurrence has been traced. However, one of the labourers on Aldabra, who had previously lived on Cosmoledo for more than ten years, assured me that it still occurs on South Island. Like the case of the rail, this is worth further investigation. A relic population might still survive--in contrast to the situation on Assumption, where extirpation is complete.

Geopelia striata — Barred Ground-Dove

On Menai, I had a quick view of a small long-tailed dove, which I took to be this species, not *Oena capensis*, which occurs in Malagasy as well as in Africa. I only saw the one bird, which may represent a not very successful artificial introduction. Elsewhere, as in the Seychelles and on Farquhar, this eastern species evidently thrives (Watson et al. 1963, 170, 188; Stoddart and Poore 1970), but there seems to be no previous suggestion of its occurrence in the Aldabra archipelago.

<u>Cisticola cherina</u> Malagasy Grass-Warbler

Bergne (1901) lists "Allouette", French for a lark. He may well have seen <u>Cisticola cherina</u>, brown above striped blackish, and white below, in general colour resembling a typical lark. It is not mentioned by Dupont (1907), nor by Fryer (1911). It is recorded from Menai by Vesey-FitzGerald (1940, 488), and apparently from both Menai and West North Islands by Hartman (1958). Gaymer found it plentiful on Menai in November 1964 and October 1965, as I and Diamond did on Wizard and Menai. Diamond often heard a "tic" alarm-call, reminiscent of that of a Robin <u>Erithacus rubecula</u> in England. Stoddart and Poore heard this call and saw birds both on the southern dunes on Menai and on the path across champignon north of settlement in September 1968. On Wizard Diamond found a nest containing three eggs, in a bushy <u>Achyranthes</u> 0.6 m above the ground. This is rather high: the greatest height which Rand (1936, 450) gives is 450 mm. The entrance was near the top. Hartman (1958) and Watson et al. (1963, 198) imply that the bird was artificially introduced to Cosmoledo and Astove. This seems most unlikely, and it is virtually certain that colonisation (from Malagasy) was unaided by man. There may be no instance of the successful artificial introduction of an insectivorous warbler in any part of the world.

Vesey-FitzGerald (1940, 488) collected a specimen on Astove. It was sent to the British Museum, but cannot now be found. Hartman collected a male on Menai, Parker three males on Menai and two on Astove. In all, sixteen specimens are available from these two islands and Wizard. Twelve of them are adult, in breeding dress. Their measurements in mm, and of material in this dress from Malagasy, in the British Museum, with the addition of a few in the University Museum of Zoology, Cambridge, are as follows:

	Wing	Tail	Culmen from base
		Malagasy	
19 ♂♂	50 - 52 (50.8)	37 - 42 (39.4)	11.5 - 13 (12.3)
15 ♀♀	45 - 48 (47.1)	36 - 41 (38.9)	11 - 13 (13.0)
		Astove	
3 ♂♂	51 52 53	38 39 40	12.5 13 13
3 ♀♀	47 47 48	34 38 39	12 12.5 12.5
		Cosmoledo: Menai Island	
4 ♂♂	51 52 52 52	37 38 39 42	11.5 11.5 12 12.5
		Cosmoledo: Wizard Island	
2 ♂♂	50 50	38 39	12.5 13
3 juv.♂♂	47 48 48	40 42 42	12 12 one broken
1 juv.♀	45	41	11

The juveniles are suffused with rusty above and on the flanks, as described by Lynes (1930, 113) for Malagasy. The juvenile female is also washed with sulphur on the chin, throat and chest. Whereas my adults had the palate wholly black, all four juveniles had black restricted to a small area in the centre, the female without any black

at all. Also, they had irides grey-brown instead of red-brown, and in two at least skull-ossification had barely started. Probably none is more than about two months old (from date of hatching), and they are assumed to be from eggs laid not earlier than December. They are probably fully grown, nevertheless their measurements are kept separate.

The wing-lengths suggest that, while the Astove and Menai birds are similar in size to those from Malagasy, those from Wizard are slightly smaller, particularly if the juveniles are taken into consideration. Weights (in g) also tend to bear this out. Using also data from Parker's specimens as well as my own, the result is as follows:

Astove			
3 ♂♂	9	10	10.8
3 ♀♀	8.4	8.5	10.8

(The heaviest female contained an enlarged, yolking egg)

Cosmoledo: Menai Island			
3 ♂♂	10	10	10

Cosmoledo: Wizard Island			
2 ♂♂	9.5	9.7	
3 juv.♂♂	8	9	9.4
1 juv.♀	8.2		

It can be seen that the Wizard males are lighter than those from Astove and Menai, the only exception being the Astove male weighing only 9 g. Also, the juvenile female from Wizard is slightly the lightest female. The investigation could be taken further by trapping and weighing of live birds at the same time of day.

As to colour, absolutely no variation could be discerned, and the known range of *Cisticola cherina* must be extended to include Astove and Cosmoledo. The two atolls may have been colonised quite recently, though in 1937, according to Vesey-FitzGerald, the species was already abundant on Astove. It is a pity that Nicoll (1906, 705) was unable to visit Astove and Cosmoledo, as we could have been reasonably sure from the account that he would have written what the situation was in 1906, and the inference from Bergne that it was already on Cosmoledo in 1901 would have been further illuminated. The fact that neither Dupont nor Fryer mentions it does not necessarily mean that it was absent at the time of their visits. Unlike Nicoll, they were not primarily ornithologists. Nicoll (1906, 686-692) visited Gloriosa in 1906, but makes no mention of *C. cherina*. It would be interesting to know whether it is there now.

Perhaps in due course Aldabra and Assumption will also be colonised. S. A. Renvoize (personal communication) is unaware of any difference in the species of grasses on the four atolls to account for its presence only on Cosmoledo and Astove. On the other hand, from the physiognomical aspect, on Aldabra there is no habitat comparable to the fairly open plantations with grassy ground cover found on Menai and Astove, or the low scrub on Wizard and Astove.

It would be interesting to ascertain how extensive the breeding season is on Cosmoledo and Astove. Parker's specimens, collected in early October, were already in breeding dress. The differences between breeding (summer) and non-breeding (winter) dress are clearly and correctly given by Lynes (1930, 112). For south-central Africa, Benson, Brooke and Vernon (1964, 83) give 82 egg-laying records for the related C. juncidis, all within the period November-June (only three for November, and a marked fall-off in the last three months). Yet Rand (1936, 449) expresses the opinion that cherina probably breeds throughout the year in Malagasy, and gives several records suggesting egg-laying in August and September (one definitely for the latter month). Nor are specimens in breeding dress on Cosmoledo and Astove in early October in keeping with the data for juncidis. Thus cherina would appear for some reason to be more plastic in its season. As would be expected in juncidis too, breeding was still under way on Cosmoledo and Astove in March. Apart from the nest with eggs found by Diamond, the heavy female collected on Astove held an egg measuring as much as 10 x 15 mm.

In order of predominance (numbers of individual specimens in each group), the stomach-contents of my specimens as a whole, including those from Astove, were:

Hemiptera: Homoptera and Heteroptera, including one Reduviidae nymph
Coleoptera: including Nitidulidae and Curculionidae
Orthoptera: including Tettigonoidea and Acridoidea
Diptera: including Fannia sp. larvae (Muscidae), Scenopinidae, and Asilidae
Hymenoptera: winged ants
Neuroptera: Myrmelionidae
Arachnida: small spiders

Corvus albus — Pied Crow

Listed from Cosmoledo by Dupont (1907, as C. scapulatus) and by Bergne (1901, as "Corbeau"). Vesey-FitzGerald (1940, 488) gives it as a visitor only. Hartman (1958) records a pair from West North Island; Bourne (1966) a pair on Menai, "the first for many years". I saw a pair on Menai, but was told that these were the only birds on the atoll as a whole. But Gaymer's information is that there were as many as five on Menai when he was there on 1 October 1965. Two of these he saw.

Zosterops maderaspatana — Malagasy White-eye

Vesey-FitzGerald (1940, 488, as Z. aldabrensis) records it as common on Cosmoledo (no particular island specified), as does Hartman (1958) for Menai. The only other record of white-eyes on Cosmoledo is of one seen by Gaymer on Menai on 1 October 1965. None was seen by any of our party on either Wizard or Menai, though it was seen by Stoddart and Poore on Menai in September 1968.

Three specimens collected on Menai have been studied (Benson 1969), and described as a distinct subspecies, differing from the population of nominate maderaspatana on Astove in being paler green above and paler

yellow on the throat and under tail-coverts. But it has since been ascertained from Vesey-FitzGerald that the specimen collected in his name (on 15 April 1952) was kept in alcohol, probably for several months, before being skinned by J. G. Williams in Nairobi. It is also understood from Mrs Stickney that Hartman's specimens may have been in alcohol for as long as one year. It is possible that the pallor of all three Menai specimens may be due to immersion in alcohol, and the validity of Z. m. menaiensis Benson requires further investigation. The special interest of Hartman's two specimens is however that they are partially grey and partially green above. It is unlikely that this was caused by alcohol. They seem to closely resemble the only known specimen of Z. hovarum Tristram, which probably came from Malagasy. The other specimen is wholly green above.

Nectarinia sovimanga — Souimanga Sunbird

The species is listed from Cosmoledo by Dupont (1907, as Cinnyris abbotti). Fryer (1911, 430) records a Cinnyris; Vesey-FitzGerald (1940, 487) records the species as "especially common" on Menai; Hartman (1958) as "very common" on Menai, "common" on West North Island; and Bourne (1966) "many" Nectarinia sp. on Menai. On Wizard we did not find it to be common. On Menai it was more so, though not as numerous as Cisticola cherina. Vesey-FitzGerald found a nest containing young (he does not say how many) on West North Island on 5 October, and Hartman saw a nest containing two eggs on Menai, during 13-15 December. Gaymer reports that the birds were plentiful on Menai in November 1964 and October 1965. I collected on Wizard two old nests, now in the British Museum (Natural History). Each was about 1 m above the ground, attached to a bush identified by S. A. Renvoize as Azima tetracantha. This plant is well equipped with large spines, which might help protect the nests and their contents from any enemies. Three juvenile males collected by Parker on Menai on 6 October, the bills of which are recorded as "black with yellow gape", and a juvenile female by Vesey-FitzGerald on 15 April, for further details of all four of which see below, are probably only about one month old from date of hatching, suggesting egg-laying respectively in August and late February or early March. On Aldabra, occupied nests with eggs have been found throughout the period August to March, and presumably this also applies on Cosmoledo. There may even be some breeding throughout the year, as with some Nectarinia spp. in south-central Africa (Benson, Brooke and Vernon 1964, 93-95).

Taking into consideration the material (Benson 1967, 85) in which N. s. buchenorum was represented by only three specimens, all from Menai, and that recently collected, including Hartman's specimens (Astove, 2 ♂♂ 1♀ ; Menai 2♂♂ 1♀ ; Assumption 1♂ 1 juv.♀ ; Aldabra 1♂), revised measurements in mm are as follows:

	Wing	Tail	Culmen from base
		Astove (buchenorum)	
7 ♂♂	54 - 57 (55.1)	39 - 43 (40.6)	17.5 - 20 (19.1)
5 ♀♀	50 - 53 (50.8)	35 - 36 (35.2)	16 - 19 (17.5)
2 juv. ♀♀	49 50	33 35	16.5 19
		Cosmoledo: Wizard (buchenorum)	
1 ♂	55	39.5	20
1 ♀	51	34+	19.5
		Cosmoledo: Menai (buchenorum)	
6 ♂♂	54 - 57 (55.5)	39 - 44 (40.2)	18 - 20 (18.8)
3 juv. ♂♂	52 53 55	34 36 37	17 18 19
2 ♀♀	51 53	33 36	17 18.5
1 juv. ♀	50	31	16
		Assumption (abbotti)	
6 ♂♂	53 - 55 (54.3)	37 - 41 (39.2)	19 - 21 (20.0)
1 ♀	49	34	16+
1 juv. ♀	49	32	18
		Aldabra (aldabrensis)	
20 ♂♂	51 - 55 (52.7)	33 - 40 (37.8)	18 - 21 (19.5)
2 juv. ♂♂	50 51	32 33	19.5 20
12 ♀♀	47 - 50 (48.4)	30 - 35 (32.5)	17 - 19 (18.2)

Specimens not indicated as juvenile are certainly fully grown, and measurements of wing indicate that Astove and Cosmoledo birds are larger than those from Aldabra, with Assumption birds intermediate. Astove and Cosmoledo birds also average larger than those from Malagasy and Gloriosa, see figures for the latter two areas in Benson 1967, 85. They also have proportionately shorter bills than any others.

Of the material now available, much more comprehensive than I had previously, in the first instance adult males may be considered. The existence of an off-season dress was denied (Benson 1967, 88), but it is now evident that, as in some African species (Skead 1967, 20-24), it does exist, at least in aldabrensis and abbotti, and probably in all the subspecies. Ten specimens of aldabrensis are in full metallic (breeding) dress, with the red chest-band fully developed. Most of the remainder (another ten) have this dress only partially developed, with the upperside largely dull olive, and the lower abdomen always dull olive-yellow instead of dingy white. They appear to represent an off-season dress. In the white of the abdomen, those in breeding dress only differ from specimens of apolis, of dry south-western Malagasy, in that it is less bright, not so pure a white. Three of the males of abbotti, collected by Nicoll on 12-13 March, also appear to be in an off-season dress. The other three differ from males in breeding dress of aldabrensis in having the abdomen mainly black, with a relatively little dingy white on the lower abdomen, while the rump and upper tail-coverts have some metallic green instead of being plain black. All the males from Astove and Cosmoledo (buchenorum) appear to be in breeding dress, with no constant

difference apparent between the two atolls. White on the abdomen has almost disappeared. In some specimens the process is complete, in others some of the feathers of the lower abdomen have whitish fringes. Metallic green on the rump is more extensive than in abbotti, while the lower back is black instead of olive as in abbotti and aldabrensis.

I stated (1967, 84) that buchenorum can also be distinguished by the brownish, less reddish tone of the chest-band. This is not borne out by the relatively long series now available. The colour in the type of buchenorum the only adult male of this subspecies which I had previously seen is almost a brick-red, and is quite accurately reproduced in the colour plate accompanying the original description (Williams 1953). According to the colour-chart of Villalobos-Dominguez and Villalobos (1947), it is nearest to SSO 8°(9). Specimens of nominate sovimanga are about the same, though the band is narrower, as it also is in apolis. In the other males of buchenorum the colour is more scarlet in tone, according to the same colour chart nearest to S 9°(6). Only Hartman's two males from Menai show some tendency to brick-red. In apolis, abbotti and aldabrensis the colour is always scarlet rather than brick-red, and the latter colour is only normal in nominate sovimanga. The type of buchenorum, also two females, one adult, one juvenile, were collected in Vesey-FitzGerald's name on the same day (15 April 1952) on Menai. He has told me that, like the specimen of Zosterops maderaspatana, they were kept in alcohol before being skinned in Nairobi. According to Mrs Stickney, certain of Hartman's specimens were also in alcohol prior to skinning, and this is the cause of the brick-red chest-band in some of the adult males, which are otherwise normal in colour.

Of adult females, Vesey-FitzGerald's specimen does not appear to have been affected by alcohol, but a Hartman specimen from Menai lacks the usual wash of yellow on the underside, and was in alcohol for one year. Material of nominate sovimanga is distinctly washed with olive on the upperside, and a relatively bright yellow below. In buchenorum (disregarding Hartman's female from Menai), abbotti and aldabrensis the upperside is brown with little or no olive wash, and the yellow wash on the underside is much less bright. In these respects these three subspecies from the Aldabra archipelago do not seem distinguishable from one another. Four specimens of apolis are like those from the Aldabra archipelago on the upperside, though perhaps a trifle paler. On the underside they are white with no yellow wash except for a slight sign of it in two from Tabiky. Four of the Astove specimens show a variable degree of orange-red fringing to the feathers of the chest, and the one which has this most pronounced, collected by Parker, also has some metallic bluish-green fringes to the feathers of the crown, nape and mantle. One old specimen of aldabrensis in the British Museum also shows slight signs of this orange-red fringing. M. P. Stuart Irwin has shown me in the National Museum of Rhodesia, Bulawayo, females of two African species, N. bifasciata and mariquensis, the odd individual of which shows the same tendency to red fringing on the chest. Benson and Irwin (1966) also note this in N. bourieri.

Of six specimens whose extreme youth is shown by uniform sooty chin and throat, a male from Aldabra and three collected by Parker on Menai agree with each other in being washed with dull olive above and olive-yellow below. But a juvenile female each from Menai and Assumption, respectively Vesey-FitzGerald and Hartman specimens, lack any olive above or yellow below. This is certainly attributable to immersion in alcohol. Another juvenile male from Aldabra, somewhat older, agrees best in colour and pattern with adult females, though has some olive above. It lacks the sooty chin and throat. The younger of the two Aldabra juvenile males, and one of the three from Menai, have no metallic feathers at all, the others only a few. Two juvenile females from Astove are like adult females but are more olive above.

It may be helpful to give the following summary of the subspecies, based only on males in breeding dress, noting that females of nominate _sovimanga_ are richest in colour, _apolis_ the least so, the other three subspecies rather richer than _apolis_:

N. s. sovimanga (Gmelin): Abdomen yellow, black restricted to uppermost part. Chest-band brick-red, relatively narrow. Wing 51-56 mm. Gloriosa and Malagasy except the dry southwest.

N. s. apolis (Hartert): Like last, but abdomen white, chest-band scarlet. Dry southwestern Malagasy.

N. s. buchenorum (Williams): Abdomen almost or completely black; chest-band scarlet, and broader. Lower back black instead of olive as in the last two; rump and upper tail-coverts metallic green instead of black. Larger, wing 54-57 mm. Bill proportionately shorter than in all four other subspecies. Astove and Cosmoledo.

N. s. abbotti (Ridgway): Like _buchenorum_, but some white on lower abdomen, lower back olive, metallic on rump less extensive. Slightly smaller than last, wing 53-55 mm. Assumption.

N. s. aldabrensis (Ridgway): Like _abbotti_, but lower abdomen wholly dingy white (not so bright as in _apolis_ or nominate _sovimanga_); rump and upper tail-coverts wholly black, without any metallic. Wing 51-55 mm. Aldabra.

No plausible explanation can be offered for the extensive black in the male of _buchenorum_, both on the abdomen and on the lower back. If it is the effect of melanism, then it is puzzling that the female shows no richness of colour. It is very like the female of _abbotti_ and _aldabrensis_, and only slightly richer than in the dry country _apolis_. The males of _apolis_ and of _aldabrensis_ (in breeding dress) are rather similar. The only colour differences are that _apolis_ has the scarlet chest-band narrower, and the abdomen a brighter white, with the black on the upper abdomen more restricted.

While on Astove, Diamond noted that this species appeared to be larger than on Aldabra, thus agreeing with inference made above from wing-lengths. The following weights in g from specimens collected by me do not support this very well:

		Astove	
3 ♂♂	6.8	7.6	7.6
2 ♀♀	6.0	7.2	

(The heavier female contained an enlarged, yolking egg)

	Wizard
1 ♂	7.2
1 ♀	6.9

	Aldabra
12 ♂♂	6.4 - 7.9 (7.1)
6 ♀♀	5.7 - 6.8 (6.3)

Nevertheless, trapping and weighing the live birds at the same time of day might well demonstrate a more marked difference.

In adults of buchenorum which I collected on Astove and Wizard, males had the flesh-coloured palate suffused with black, whereas in females there was no such suffusion. The stomach-contents of specimens collected by Parker on Menai consisted of fragments of insects, including some Coleoptera. Those of a male and a female taken by me on Wizard consisted of small Arachnida (spiders) and Homoptera.

Serinus mozambicus — Yellow-fronted Serin

Bergne (1901) lists "Sourin", "greyish yellow" in colour. This name may be a corruption of "Serin". S. mozambicus is a common and widespread species in southern Africa, and is sometimes kept as a cage bird. It is greyish green above, yellow below. It has been introduced to Desroches, in the Amirantes (Watson et al. 1963, 182), as well as to Mauritius and Reunion (ibid., 148, 159), and an introduction to Cosmoledo would not be surprising. But there is no subsequent record, and so presumably it died out long ago.

Possibly resident shore birds

Ardea cinerea — Grey Heron

Listed by Dupont (1907). Between us, Diamond, Grubb and I saw at least five individuals on Wizard, and two more on Menai.

Egretta garzetta — Little Egret

Dawson (1966, 7, under E. dimorpha) records that it occurs on Cosmoledo "in large flocks", though we have no evidence of this. There were however at least five birds on Wizard at the time of our visit. I counted three dark phase individuals, one white. On Menai, Diamond counted 13 dark phase birds, four white. Bourne (1966) refers to egrets and herons as abundant on Menai, of which some at least were presumably E. garzetta.

Parker collected a female on Menai, and I collected a female on Wizard. Some particulars for them are:

Locality	Menai	Wizard
Wing	277 mm	287 mm
Culmen from base	90 mm	92 mm
Culmen exposed	88 mm	90 mm
Colour of plumage	bluish grey, chin, throat and outer primary coverts white	similar, but in fresher dress, bluish grey darker
Colour of soft parts	upper mandible blackish, lower blackish at tip; rest pale horn; front of tarsi black, back and toes greenish yellow	bill black; orange-yellow at base and around eye; legs black, feet yellow; irides yellow
Weight	-	540 g

According to me (Benson 1967, 68), E. assumptionis does not seem recognisable, and these two specimens must be assigned to E. g. dimorpha, of Malagasy and the Aldabra archipelago. Their bill-lengths are lower than the minimum given by Grant and Mackworth-Praed (1933, 193) for assumptionis.

Bubulcus ibis — Cattle-Egret

No earlier record has been traced. Inland on Wizard, there were some fifty individuals at least. In the south, Grubb counted 15, about half with buffy breeding plumes. I saw another 34 in the north, including one flock of 19. One bird was seen on Menai. This is not strictly a "shore" bird at all, but is best treated with other Ardeidae spp.

Butorides striatus — Little Green Heron

Listed by Dupont (1907, as B. atricapillus). Only one individual was seen by us on Wizard, and a total of five on Menai. No specimen has been collected, but most likely Cosmoledo birds are B. s. crawfordi, as on Assumption and Aldabra.

Migrants

Unless otherwise indicated, the following records of shore birds are from Diamond, Grubb or myself.

Squatarola squatarola — Grey Plover

Eight on Wizard, also noted on Menai. One on Wizard was mainly in breeding dress.

Charadrius leschenaultii — Great Sand-Plover

Listed by Dupont (1907, as Aegialitis geoffroyi). On Menai and Wizard in small flocks.

Numenius phaeopus — Whimbrel

Listed by Dupont (1907). About 30 on Wizard, some perching on Agave inflorescences or on tops of Tournefortia bushes. Also noted on Menai, where Parker collected one.

Numenius arquata — Curlew

Listed by Dupont (1907), but not seen by us.

Limosa lapponica — Bar-tailed Godwit

About five seen by Diamond on Menai.

Tringa nebularia — Greenshank

Listed by Dupont (1907, as Totanus glottis). One on Wizard, two on Menai.

Actitis hypoleucos — Common Sandpiper

Listed by Dupont (1907), but not seen by us.

Arenaria interpres — Turnstone

Listed by Dupont (1907). Large numbers on Menai (Bourne 1966). At least 100 on Wizard. Also seen on Menai.

Crocethia alba — Sanderling

Seven seen by myself on Wizard, noted by Diamond on Menai.

Erolia minuta — Little Stint

Listed by Dupont (1907), but not seen by us.

Erolia testacea — Curlew-Sandpiper

In small flocks on Menai and Wizard.

Dromas ardeola — Crab-Plover

Listed by Dupont (1907). Bourne (1966) records 20 on Menai. At least 50 on Wizard, over 30 on Menai.

Of true land birds, Vesey-FitzGerald (1940, 488) records a Broad-billed Roller Eurystomus glaucurus on Wizard on 6 October 1937. It was presumably E. g. glaucurus, well known as a migrant from its breeding quarters in Malagasy to Africa. Gaymer also reports one seen on Menai on 9 October 1964 and again on 1 October 1965. He saw a single Blue-cheeked Bee-eater Merops superciliosus on Menai on 1 October 1965. This would be unusually early for the palaearctic M. s. persicus, two of which I definitely saw on Aldabra on 22 March 1968. The earliest arrival date for the subspecies in Zambia is given as late October (Benson and White 1957, 51). Gaymer's record is presumed to refer to M. s. superciliosus, suspected of migrating from breeding quarters in Malagasy to Africa. On Menai, I saw a Red-backed Shrike Lanius collurio, an adult female or an immature bird, perched at the top of a Tournefortia bush. This seems to be the only record of this palaearctic species from the Malagasy Region, and it can only be of a stray individual. Other palaearctic land birds may be expected to occur on Cosmoledo occasionally. The number of such species recorded by now from Aldabra is about 14.

Summary

1. An account is given of the land (including shore) birds of Cosmoledo.

2. Of the resident true land birds:

(a) A rail *Dryolimnas cuvieri* and a turtledove *Streptopelia picturata* are said to have existed some 60 years ago, but are now extinct except perhaps on South Island.

(b) A warbler *Cisticola cherina* may be a recent coloniser from Malagasy, and is undifferentiated from the parent stock, except that specimens from Wizard Island are rather small in size. There is a well-marked subspecies of a sunbird *Nectarinia sovimanga*, confined to Cosmoledo and Astove. A white-eye *Zosterops maderaspatana*, only known from Menai Island, may belong to the same subspecies as on Astove. Two out of the three specimens collected are remarkable for being partially grey above. The first two of these species are plentiful, the white-eye less so.

(c) A crow *Corvus albus* occurs in small numbers. There is one record of a dove *Geopelia striata*, probably introduced by man. Another such introduction may have been a serin *Serinus mozambicus*, but it has apparently died out.

3. The number of species of resident true land birds is much less than on Aldabra (see list in Stoddart, Benson and Peak 1970), despite the fact that Cosmoledo is nearer to Malagasy, the principal source of colonisation. But the land area of Cosmoledo is much less.

4. There are four possibly resident herons or egrets (family Ardeidae).

5. Of migrants, eleven species of shore birds which breed in the Palaearctic Region have been recorded; also the Crab Plover *Dromas ardeola* and three species of true land bird.

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8. GEOGRAPHY AND ECOLOGY OF ASTOVE

C. J. Bayne, B. H. Cogan, A. W. Diamond, J. Frazier, P. Grubb,
A. Hutson, M. E. D. Poore, D. R. Stoddart, J. D. Taylor

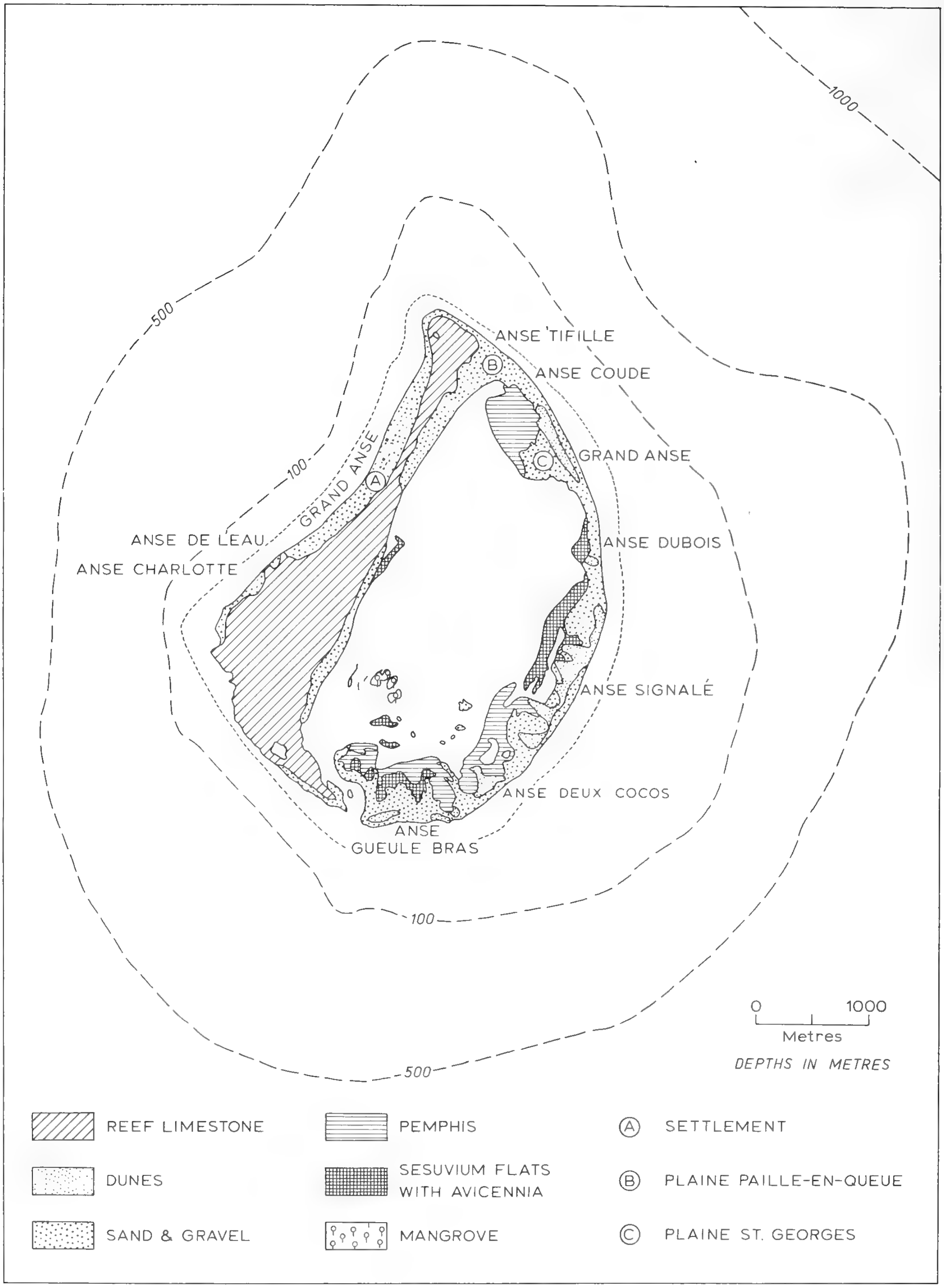
Introduction

Astove, 10°6'S, 47°45'E, is an elevated atoll with a nearly continuous land rim, located 35 km south of Cosmoledo Atoll and 145 km south-east of Aldabra. There have been fewer visits by scientists to Astove than to many of the neighbouring islands, and older records are particularly scarce. Fryer called there briefly in 1908 (Fryer 1911), following Dupont in 1906 (Dupont 1907). The main accounts are those by Vesey-FitzGerald (1942), Baker (1963), and Piggott (1961a, 1961b, 1968). Table 8 lists scientific visitors to Astove. This account is based on the literature, and on observations made during two visits by Royal Society Expedition personnel, the first by ten members on 5 March and the second by five on 14 September 1968. Most of these observations were made on the western side of the atoll, though some members visited the northern part of the east side, and Stoddart walked round the whole land rim. The first hydrographic survey of Astove was by H.M.S. _Owen_ in 1964 (Admiralty Chart 718, 1967); Figure 5 is based on small-scale aerial photography carried out in 1960, with details added from Baker (1963) and Piggott (1961b, 1968).

Geomorphology

Astove has maximum surface dimensions of 4.6 x 2.8 km: the land area is 4.25 sq km, that of the lagoon 5 sq km, and the total, including peripheral reef, about 9.5 sq km. It stands on the southernmost of two presumably volcanic peaks which rise from the ocean floor at depths of 4000-4400 m; Cosmoledo stands on the adjacent peak to the north. The atoll lagoon is very shallow, with large areas less than 0.5 m, and it has a restricted tidal range. According to the lessee, the lagoon level gradually falls in the two weeks preceding neaps until a large part of the floor is exposed. Between neap and spring tides the level rises. Thus flow into the lagoon is greater than out of it during spring tides, and _vice versa_ during neaps. The diurnal cycle is damped within the lagoon. The lagoon entrance at the south point is approximately 100 m wide, and also shallow.

Much of the west rim of Astove is formed of elevated reef-rock, which rises to 4-5 m above sea level. In the north the reef-rock is fairly smooth and partly covered with sand, but further south it is



1000
500
100
ANSE TIFILLE
ANSE COUDE
GRAND ANSE
GRAND ANSE
ANSE DE LEAU
ANSE CHARLOTTE
ANSE DUBOIS
ANSE SIGNALÉ
ANSE DEUX COCOS
ANSE
GUEULE BRAS
100
500
0
1000
Metres
DEPTHS IN METRES
REEF LIMESTONE
DUNES
SAND & GRAVEL
PEMPHIS
SESUVIUM FLATS
WITH AVICENNIA
MANGROVE
A SETTLEMENT
B PLAINE PAILLE-EN-QUEUE
C PLAINE ST. GEORGES

Fig. 5. Astove

Table 8. Scientific Studies at Astove

Date	Study	Reference
1895	S. C. E. Baty, agricultural survey and rudimentary chart	Bergne (1900); Adm.Ch.718(1911)
1901	H. A'C. Bergne, general observations	Bergne (1901)
1906 Sept.10-14	R. Dupont, fauna, flora, agricultural potential	Dupont (1907)
1907	H. L. Thomasset, insects	
1908 Aug.28-Sept.1	J. C. F. Fryer, insects, general observations	Fryer (1908, 1911, 1912); Gardiner (1936)
1910*	R. Dupont, insects, plants	
1937 Oct.	L. D. E. F. Vesey-FitzGerald, vegetation and birds	Vesey-FitzGerald (1940,1941,1942)
1952 Nov.	E. S. Brown, insects	
1956	W. Travis, underwater and general observations	Travis (1959)
1957 Dec.9	W. D. Hartman, land birds	Hartman (1958)
1960 Oct. 6-9	B. H. Baker, C. J. Piggott, geology and soils	Baker (1963); Piggott (1961a, 1961b, 1968)
1964 March 16	H.M.S. Owen, Cmdr D. W. Haslam: survey, birds	Bourne (1966)
1964	R. E. Honegger, reptiles	Honegger (1966)
1967 March 8	J. F. G. Lionnet, H. A. Beamish, insects	Lionnet (1970)
1967 Oct. 7	M. D. Gwynne, D. Wood, I. S. C. Parker, collections of plants and birds	Parker (1970); Gwynne and Wood (1969)
1967-8	Mrs R. M. Veevers-Carter and Miss T. Ridgway, collection of plants	Fosberg and Renvoize (1970)
1968 March 5	C. W. Benson, B. H. Cogan, A. W. Diamond, F. R. Fosberg, J. Frazier, A. Graham, P. Grubb, A. Hutson, K. McKenzie, S. A. Renvoize	This report
1968 Sept. 15	C. J. Bayne, J. C. Gamble, M. E. D. Poore, D. R. Stoddart, T. S. Westoll	This report
1969 June	A. W. Diamond, J. Frazier	This report

* J. A. de Gaye collected Lepidoptera, now in the Rothschild Collection, British Museum (Natural History), on Astove at a date unknown, probably c. 1910.

deeply dissected with large solution holes and is comparable to some of the more extreme Aldabra champignon. The reef-rock is known on Astove as pavé, a name which might be adopted for smoother-surfaced raised limestone which is more irregular than Aldabra platin and stands at a higher level. Baker (1963, 92-97), who calculates the area of raised reef-rock to be 236 ha or nearly 50 per cent of the total land area, has noted that the solution holes are arranged in straight lines in the reef-rock surface.

The reef-rock outcrops to form low cliffs along the southwest coast, but further north there is a seaward sand strip up to 500 m wide (forming Grand Anse) between the sea and the raised limestone. There is also a discontinuous sand strip on the lagoon side of the limestone: it is more complete in the north, where there are vegetated dunes 5-6 m high.

The eastern rim of Astove consists of low sand and gravel spreads overtopped on the seaward coast by active dunes up to 18 m high. These are highest and steepest in the north and become progressively lower and smaller southwards. There is no raised reef-rock outcropping on the surface of the east rim. Much of the seaward coast is rocky, however, though with the appearance of a massive bedded beach conglomerate, with seaward dip, rather than a raised reef-rock. This is a rough-water coast during the Southeast Trades, and because of the narrowness of the reef platform the beaches are formed by gravel, cobbles and rubble as well as sand. Patches of horizontally-bedded sandstone outcrop in places along the lagoon shore, but these may be of recent origin exposed only by the enlargement of the lagoon, and hence do not necessarily result from uplift.

The northern area linking the east and west rims, Plaine Paille-en-Queue, is a largely unvegetated gravel fan that appears to have been recently deposited. It may be either a recent channel fill in a depression formerly separating the two rims, or a cyclone deposit. It is surmounted along the seaward coast by a low sandy beach.

The fringing reef surrounding the land rim is narrow, with an average width of 250 m. On the east side it is an erosional feature, with potholes and deep grooves normal to the shore. The reef front is exceptionally steep, especially on the west side, where the bottom plunges so steeply that ships are unable to anchor and a cable must be taken inshore by small boat and an anchor lodged on the reef flat. A buoy formerly moored outside the reef near the settlement has been washed away.

Fryer (1911) considered that the raised reef-rock indicated a relative uplift of Astove by at least 18 m. The asymmetry of the atoll is striking, with reef-rock confined to the western side, with its straight, vertical (faulted?) coast, and absent from the east side. This suggests tilting rather than simple eustatic emergence of the atoll rim; the asymmetry is also evident in the 100 and 500 m isobaths (Figure 5). No evidence has yet been seen on Astove either of an 8 m ridge or

of a newer limestone at the 4 m level, as on Aldabra, but observations have been rapid and the reef-rock areas have been much altered by phosphate mining in the past.

The usual soil series have been distinguished by Piggott (1961): Desnoeufs Series on the limestone, now largely removed for phosphate; Farquhar Series on the dunes; and a variable Shioya Series, including gravelly loamy sand and loamy sand.

Vegetation

Previous workers have recorded 58 species of flowering plants from Astove (Dupont 1907, Vesey-FitzGerald 1942). Recent collections have been made by Gwynne and Wood (1969) in 1967, by Veevers-Carter and Ridgway in 1967-68, by Fosberg and Renvoize in March 1968, and by Stoddart and Poore in September 1968. These collections are listed in the following paper (Fosberg and Renvoize 1970). The flora resembles that of Aldabra, though the area of sand is much greater, and there has been more interference by man. The following vegetation types can be distinguished:

1. *Pemphis* hedge on leeward cliffs.
2. *Scaevola* hedge on leeward sand beach.
3. Mixed scrub on raised reef-rock.
4. Coconut woodland on leeward sand plains.
5. Coconut woodland on leeward stable dunes.
6. *Casuarina* woodland on the western rim.
7. Lagoon beach scrub of *Scaevola* and *Pemphis*.
8. Scrub of *Suriana maritima* on high dunes, with ground cover of *Fimbristylis cymosa*, and with scrub of *Tournefortia* and *Scaevola* in protected situations.
9. Grasslands of the exposed sand and gravel plains of the north and east sides.
10. *Sesuvium* mat of the eastern lagoon shore, with occasional *Avicennia*.
11. Dwarf mangrove woodland of lagoon islets.

The characteristics of these types can best be described in terms of their distribution round the atoll rim.

West rim

The raised limestone vegetation is similar to that of Aldabra, but more open. *Thespesia populneoides* (3 m) and *Grewia salicifolia* are the only common trees, and *Pisonia grandis*, *Euphorbia abbotti* and *Sideroxylon inerme*, all previously recorded, were not seen. The most common shrubs are *Vernonia aldabrensis* (1-2 m), *Colubrina asiatica* (2-3 m), *Azima tetracantha* and *Gagnebina pterocarpa*. Other characteristic plants are *Capparis cartilaginea*, *Lomatophyllum borbonicum*, *Cassia occidentalis* and *Euphorbia hirta*. North of the settlement the limestone outcrop is narrower, with fewer and smaller shrubs (mainly *Vernonia aldabrensis* and *Colubrina asiatica*) and with a ground cover of *Ipomoea tuba*, *Cassytha filiformis*, *Plumbago aphylla*, *Sarcostemma viminale*, *Launaea intybacea*, *Boerhavia elegans*, *Asystasia bojeriana* and *Vernonia cinerea*. This

resembles the vegetation of the more disturbed areas on the limestone near the West Island settlement on Aldabra.

The sand strip south of the raised reef-rock has a seaward hedge of Pemphis acidula 3-4 m tall, then a low dune area under woodland of Cocos and Casuarina. Cordia subcordata is common in the lee of the Pemphis hedge. The ground cover in the woodland consists of grasses (Dactyloctenium aegyptium, Enteropogon sechellensis, Cenchrus echinatus), with Cassytha, Vernonia cinerea and other plants. Gossypium hirsutum, Caesalpinia, and Ricinus communis are common under the coconuts and in the more open areas. There is a large ornamental tree of Tabebuia pallida at a small fishermen's hut in this section.

Further north the lagoonward sand strip has a discontinuous hedge of Suriana maritima and Pemphis acidula, with a woodland of Cocos and Casuarina on low hummocky dunes. Guettarda speciosa is quite common, Tournefortia argentea much less so. The woodland has a low tree storey of Guettarda, and a ground layer of long vines of Ipomoea pes-caprae and I. tuba, with Digitaria horizontalis, Fimbristylis cymosa, Boerhavia repens and Stachytarpheta jamaicensis.

The seaward sand area on the west rim has a littoral hedge of Suriana maritima and Scaevola, with Guettarda; Tournefortia is again uncommon. The coconut woodland is mostly 5-10 m tall, with some Guettarda and Vernonia beneath, but generally there is no shrub layer and only a ground cover of grasses, sedges, vines and herbs. This carpet includes Dactyloctenium aegyptium, Cenchrus echinatus, Sporobolus virginicus, Stachytarpheta jamaicensis, Euphorbia prostrata, Sida parvifolia, Boerhavia, Ipomoea tuba, Achyranthes aspera and Fimbristylis cymosa. Immediately south of the settlement the coconut woodland has a layer of scattered shrubs, with Maytenus, Barleria sp., Grewia salicifolia and Vernonia aldabrensis as well as low trees of Guettarda.

At the settlement there is a grove of tall Casuarina trees, a single Hernandia, and common introduced plants. Catharanthus roseus and Ipomoea pes-caprae are plentiful round the houses, and Agave is cultivated.

East rim

The vegetation of the east rim differs markedly from that of the west, largely in the almost complete absence of trees, except for some small chlorotic coconuts on Plaine St George, in the lee of the highest dunes, but also in the absence of raised limestone and its characteristic plants.

The high northern dunes are covered on their seaward side with a dense scrub of Suriana maritima, overgrown with Cassytha. Bare areas, especially on the tops of the dunes, have clumps of Fimbristylis cymosa, Euphorbia sp., and Boerhavia; and immediately in the lee there is less

luxuriant Suriana, with Scaevola and Tournefortia on more protected sites, and a ground cover of Fimbristylis cymosa and Sporobolus, with Portulaca oleracea, Euphorbia sp., and Sida parvifolia. The gravel and sand plains lack not only trees but also shrubs: the gravel spreads are covered with mats of Plumbago aphylla and Cassytha filiformis, the sand with Dactyloctenium aegyptium, Eragrostis sp. cf. riparia, Sporobolus virginicus, Fimbristylis cymosa, Cleome strigosa, Stachytarpheta jamaicensis and Ipomoea tuba. Much of this ground is burnt over frequently.

The lagoon shore is fringed with a low (1-2 m) scrub of Pemphis acidula or Suriana maritima, which is very difficult to penetrate, and much of which is dead. On the lagoonward side of the Pemphis there is normally a zone of bare silty sand, then a belt of fleshy Sesuvium portulacastrum, extending along most of the lagoon shore, forming a mat up to 80 m wide. There are very occasional stunted trees of Avicennia marina up to 2 m tall in this Sesuvium zone.

The islets near the south end of the lagoon support a dwarf mangrove woodland (1-1.5 m high) of Lumnitzera racemosa and Rhizophora mucronata, the former on the windward eroding shores, the latter (more rarely) on higher drier areas. Suriana and Pemphis are both present on these islets.

The northern gravel spread of Plaine Paille-en-Queue has a very sparse vegetation cover, with a line of windbreak Casuarina at its west end, and a mosaic of Stachytarpheta, Achyranthes, Boerhavia, Plumbago, Dactyloctenium and Fimbristylis. Cassytha is widespread. Pemphis acidula forms a hedge along the lagoon shore.

Fauna other than Birds

Small faunal collections were made by Fryer in 1908: in addition to insects, he collected two spiders (Hirst 1911) and two reptiles (Boulenger 1911). Honegger (1966) collected reptiles more recently, and Legrand (1965) and Lionnet (1970) the Lepidoptera. Further collections were made by the Royal Society party in March 1968.

The littoral fauna and flora resemble those at Aldabra. On the west rim, near the Settlement, the reef flat is sandy and covered with marine grasses, of which Cymodocea predominates toward the seaward edge. Low overhanging cliffs to the north have a fauna which includes the snails Nerita plicata and Nerita undata, the large chiton Acanthopleura brevispinosa, the limpet Cellana cernica, a red xanthid rock crab, and the grapsid Grapsus tenuicrustatus. Echinometra matthai was also collected on the flat. On the east coast, near the high dunes, the cliff is formed by a rough champignon sloping down to an abrasional flat. The cliff lacks the pinnacles and pools of similar cliffs at Cinq Cases, Aldabra, and there is no spray fauna such as that associated with Cinq Cases rock pools. Grapsus tenuicrustatus, Coenobita rugosa and C. perlatus were observed here. Round the lagoon shore there are

wide muddy flats. In the north there are abundant Uca holes in the mud, as well as numerous large elliptical holes occupied by the giant portunid crab Scylla serrata. On the lagoon shore there are many mollusc shells, both of bivalves and Cerithium. Table 9 lists the marine mollusca and Table 10 the Decapod Crustacea collected by P. Grubb in 1968, and identified by J. D. Taylor.

Astove is an important nesting ground for Green Turtle, Chelonia mydas, though on a smaller scale than formerly: Baty in 1895 was told of 150 being taken in a single 24 hour period (Bergne 1900). Hirth (FAO 1967) considers that Astove has the largest Green Turtle rookery in the Aldabra group, though he gives no evidence for this. Hawksbill turtle are said to be rare.

Of the land fauna, Rothschild (1915) records the former existence of the Giant Land Tortoise Geochelone gigantea, now extinct, and Fryer (1911) records the finding of remains in the raised limestone. No historical records of its presence on Astove are known. Three other reptiles are found: Phelsuma astricta astovei FitzSimons (Mertens 1962), a brightly coloured form; Hemidactylus mercatorius (Honegger 1966); and Ablepharus boutonii. All were seen in 1968 in the settlement area, and Ablepharus was also seen on lagoon islets. All three genera are common on southwest Indian Ocean coral islands. Among the land Crustacea, Birgus latro and Cardisoma carnifex are conspicuous.

Table 11 keys the literature on the small recorded insect fauna of Astove found in the Percy Sladen Expedition reports. Collections made by Cogan and Hutson in 1968 will probably increase the known insect fauna from less than 30 to more than 100 species, in spite of only about six hours collecting. The vegetation on Astove, like that on Cosmoledo, is more luxuriant than on Aldabra, and this is reflected in the insect population. This shows a great variety of form, including many of the species found on Aldabra and Cosmoledo, with one or two striking additions. The large dark brown Hemipteran Anoplocnemis curvipes (Fab.) was particularly noticeable, and although this species has been taken in Aldabra in the past it has not been found there during the present expedition. The composition of the insect fauna appears to be very similar to that of the other islands in the Aldabra group. It consists of a large Ethiopian element with strong Malagasy connections, the remainder consisting of cosmotropical species together with a small number of endemics. These generalisations are based on previously recorded material and a preliminary survey of the 1968 material. So far the 1968 collections have been found to include one Dolichopodid fly of the genus Sciapus endemic to Astove, and a probable new subspecies of the Pierid butterfly Colotis evanthides Holl.

Astove is noted for its Lepidoptera (see also the subsequent paper by Lionnet, 1970), but this is not the result of a very rich fauna, but of favourable conditions for the presence of very large numbers of certain species, such as Acraea ranavalona Boisd. and Junonia clelia epiclelia Boisd. Another Junonia, J. rhadama Boisd., a brilliant blue

Table 9. Mollusca collected on Astove, 1968

Gastropoda

Trochus flammulatus Lamarck
Tectus mauritianus (Gould)
Turbo argyrostomus Linnaeus
Nerita albicilla Linnaeus
Nerita plicata Linnaeus
Nerita polita Linnaeus
Nerita textilis Dillwyn
Nerita undata Linnaeus
Phasianella aethiopica Philippi
Philippia hybrida (Linnaeus)
Cerithium articulatum Adams and Reeve
Cerithium columna Sowerby
Cerithium echinatum Lamarck
Hipponyx conica Schumacher
Strombus gibberulus Linnaeus
Strombus mutabilis Swainson
Polynices melanostoma (Gmelin)
Cypraea annulus Linnaeus
Cypraea carneola Linnaeus
Cypraea erosa Linnaeus
Cypraea helvola Linnaeus
Cypraea histrio Gmelin
Cypraea isabella Linnaeus
Cypraea lynx Linnaeus
Cypraea moneta Linnaeus
Cypraea vitellus Linnaeus
Phalium achatina Lamarck
Cymatium nicobaricum (Röding)
Cymatium pileane (Linnaeus)
Bursa granularis Röding
Tonna perdix (Linnaeus)
Quimalea pomum (Linnaeus)
Drupa margariticola (Broderip)
Morula granulata (Duclos)
Nassa francolina (Bruguière)
Engina mendicaria (Linnaeus)
Nassarius grandiosa (Hinds)
Nassarius muricatus (Quoy and Gaim.)
Latirus craticulatus (Lamarck)
Peristernia nassatula (Lamarck)
Cantharus undosus (Linnaeus)
Mitra stictica (Link)
Strigatella litterata (Lamarck)
Chrysame fraga (Quoy and Giamard)
Pterygia nucea (Gmelin)
Vasum turbinellus (Linnaeus)
Conus arenatus Hwass
Conus coronatus Gmelin
Conus ebraeus Linnaeus
Conus flavians Lamarck
Conus pulicarius Hwass
Conus rattus Hwass
Terebra affinis Gray

Bivalvia

Modiolus auriculatus Krauss
Septifer bilocularis (Linnaeus)
Gafrarium pectinatum (Linnaeus)

Collected by P. Grubb; identified by J. D. Taylor; incorporated into the collections of the British Museum (Natural History), accession number 2214.

Table 10. Crustacea (Decapoda) collected on Astove, 1968

Grapsus tenuicrustatus (Herbst): 2♀ 1♂
Metopograpsus messor (Forskål): 2♀ ovig.
Pachygrapsus polyodus (Stebbing): 1♂
Percnon guinotae Crosnier: 1♂
Thalamita prymna (Herbst): 1♂
Charybdis orientalis (Dana): 2♀ ovig.
Actaea ruppelli (Krauss)
Chlorodiella niger (Forskål): 1♂
Phymodius monticulosus (Milne Edwards)
Phymodius ungulatus (Milne Edwards): 2♂
Epixanthus frontalis (Milne Edwards): 1♂ 3♀
Xanthias lamarckii (Milne Edwards): 2♂
Liomera monticulosus (Milne Edwards): 1♂
Lachnopodus subacutus (Stimpson): 1♀
Atergatis floridus (Linnaeus): 2♂
Zozimnus aeneus (Linnaeus): 1♀
Eriphia laevimanus (Guérin): 1♀
Eriphia scabicula (Dana): 1♀
Lybia tessellata (Latreille): 1♂ 1♀
Madaens granulosus (Haswell): 1♀
Coenobita perlatus (Milne Edwards): 1♀
Coenobita rugosus (Milne Edwards)
Pagurus megistos (Herbst): 1
Pagurus pedunculatus (Herbst): 3
Calcinus elegans (Milne Edwards): 2
Calcinus laevimanus (Randall)
Clibanarius striolatus (Dana)
Clibanarius virescens (Krauss)

Collected by P. Grubb; identified by J. D. Taylor; incorporated into the collections of the British Museum (Natural History).

Table 11. Insects recorded from Astove by the Percy Sladen Expedition

Group	Number of species	Reference
Orthoptera	2	Bolivar (1912, 1924)
Hemiptera	2	Green (1907), Distant (1913), Mamet (1943).
Lepidoptera	5	Fryer (1912)
Coleoptera	7	Champion (1914), Gebien (1922), Schenkling (1922), Scott (1912)
Hymenoptera	6	Burr (1910), Turner (1911)
Diptera	2	Lamb (1912)

Nymphalid, is found on Astove, presumably colonising from Malagasy, but it has progressed no further in the Aldabra group. Unfortunately it appears to be decreasing in numbers and was not seen by the 1968 party. Fryer in 1908 found it not uncommon along the lagoon shore (Fryer 1912).

Another less pleasant part of the insect fauna, very much in evidence, is the mosquito *Aedes (Ochlerotatus) fryeri* Theo., found in very large numbers. This species breeds in brackish and salt water in the crab-holes along the shore, and the human inhabitants must often sit in clouds of smoke for protection in the evenings.

Birds

The land bird fauna is small and very similar to that of Cosmoledo; it is considered in detail by Benson (1970) in a later paper. Of the six probably resident land birds, two (*Dryolimnas cuvieri*, *Streptopelia picturata*) have not been recorded since 1906 and 1908 respectively (Dupont 1907, Fryer 1911) and are certainly extinct. *Corvus albus* is present in very small numbers. *Cisticola cherina* is the most abundant land bird, followed by *Nectarinia sovimanga*; the white-eye *Zosterops maderaspatana* is not common. In addition to these land birds considered by Benson, Stoddart was informed that pigeons inhabited a large bird box in a tall *Casuarina* at the settlement, but he did not see the birds, which may have been recently introduced. Benson lists four shore birds as possibly resident: *Ardea cinerea*, *Egretta garzetta*, *Bubulcus ibis* and *Butorides striatus*. Adults and young of *Ardea cinerea* were seen in June 1969 by Frazier and Diamond.

The sea bird fauna is unusually impoverished, presumably as a result of the lack of suitable habitat for tree-nesting birds (the absence of mangroves, for example), the degree of human interference, and the continuity of the land rim and resulting lack of isolated refugia. Sea birds have been recorded by Dupont (1907), Vesey-FitzGerald (1941), and Bourne (1966). Diamond made observations on the western rim briefly in March 1968. The only sea birds seen were one or two adult Caspian Terns *Hydroprogne caspia* and three Crested Terns *Thalasseus bergii*. The site of a small colony of terns, probably Sooty Terns *Sterna fuscata*, was found on the islet Petit Astove off the western extremity of the atoll. Frazier saw the Caspian Tern in the lagoon on the same occasion, and Stoddart two of the same species on the eastern rim in September 1968. Frazier also saw the Crested Tern over the lagoon in March.

Previous records are scanty, and often refer to the Aldabra archipelago generally rather than to Astove itself. They may be summarised as follows:

Phaethon lepturus

Recorded from the archipelago by Watson et al. (1963).

Sula sula
Recorded by Watson et al. (1963) as "formerly" occurring. Seen on the west side by Hartman (1958) and by H.M.S. Owen (Bourne 1966).

Fregata ariel

Fregata minor
Both species recorded generally in the archipelago by Dupont (1907).

Hydroprogne caspia
Seen in March by Diamond and Frazier on the west side and in the lagoon; in September by Stoddart on the east side; and in October by Vesey-FitzGerald (1941, 527). Young seen with adults in June 1969 by Frazier and Diamond.

Sterna fuscata?
Colony probably of this species on Petit Astove, noted by Diamond.

Sterna albifrons
Recorded by Dupont (1907), as S. minuta.

Thalasseus bergii
Recorded by Bourne (1966); three seen by Diamond. Young seen with adults in June 1969 by Frazier and Diamond.

Gygis alba
Recorded by Dupont (1907).

Seychellois labourers on Aldabra, who were familiar with Astove, said that both "Diament" (a Creole term covering three species of tern but here most likely to be the Black-naped Tern Sterna sumatrana) and Audubon's Shearwater Puffinus l'herminieri nest on Astove. Even if this were confirmed, Astove would still have the most impoverished sea bird avifauna in the archipelago. In addition to the lack of trees for nesting of such species as Fregata spp., Sula sula and Gygis alba, there are very few of the small islets favoured by Noddy Terns Anous stolidus, Black-naped and Crested Terns, Sterna sumatrana and Thalasseus bergii and Yellow-billed and Red-tailed Tropic Birds Phaethon lepturus and P. rubricauda.

Settlement

Little is known of the early history of Astove. A Portuguese slaver Don Royal is said to have been wrecked there, probably in the eighteenth century, and the survivors to have lived on the atoll for 30-40 years. Other vessels were certainly wrecked, and the remains of some can still be found on the western reefs. Two old graves formerly existed on the west shore. At the time of Sebert Baty's survey in 1895 (Bergne 1900), the atoll was uninhabited, and there were only six coconut palms on the entire island, one of them at the landing place on the west side.

In that year James Spurs left four men there for fishing and built a hut 100 m south of the palm tree on the west shore. Because of lack of rain for six months, water had to be landed for these first settlers. Bergne (1901) found the settlement deserted six years later and the buildings destroyed. Though Baty had forecast that maize would probably be a failure, 150 acres (60 ha) had been cleared for this crop by 1901, a few hundred coconuts had been planted, and tomatoes and pumpkins had been cultivated. Five labourers were left there, and Fryer (1908) found gourds, pumpkins, water melons, maize and tobacco to be cultivated.

No details have been traced of the progress of the guano mining industry on the atoll. According to Baker (1963, 92-97), 72,162 tons of guano were exported between 1927 and 1960, leaving reserves (Baker 1963, 124) of less than 5,000 tons. Baker's analyses of the guano gave a phosphate (total P_2O_5) content of 25-29 per cent.

By 1960 (Piggott 1961) 100 ha were planted to coconut palms, but the yield (15 tons per annum or 7 nuts per tree per year) was very poor, presumably as a result of low rainfall, cyclones, or poor management. Piggott states that the maximum area possible for coconut growing is 240 ha. Since Piggott's survey the lease has changed hands, and the present lessee, Mr R. M. Veevers-Carter, is vigorously developing the plantations with the aid of a tractor and small labour force. Maize has long been grown on the low stable dunes in the wet season. Other crops include sisal, cotton, sweet potatoes. Baty in 1895 had found numerous rats but no goats. Chickens and pigs were introduced at an early stage, and the present lessee has introduced turkeys, ducks and cattle. Giant Tortoises have been introduced from Aldabra, and the lessee hopes to introduce many other animals, and to establish a turtle hatchery. He is at present building a large new house south of the present landing point.

Between 1814, when the administration of Mauritius passed from the French to the English, and 1903, when the new colony of Seychelles was formed, Astove was administered from Mauritius. It now forms part of the Colony of Seychelles, and was not included in the British Indian Ocean Territory in 1965.

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* We regret to announce the untimely death of Mr. Mark Veevers-Carter in Mombasa on March 11, 1970 [Eds.].

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9. PLANTS OF ASTOVE ISLAND

F. R. Fosberg and S. A. Renvoize

CYMODOCEA [CILIATA]
Seen by Grubb (1968).

CENCHRUS ECHINATUS L.
S. l., Ridgway 8 (Fo); Veevers-Carter 8 (EA); north of Settlement, Stoddart & Poore 1286 (K); West side, Stoddart & Poore 1279 (K); Grand Anse, Fosberg 49704 (US, K); north of Settlement, Renvoize 1212 (US, K).

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
S. l., Gwynne & Wood 1320 (K, EA); Ridgway 31 (Fo); Veevers-Carter 31 (EA); north of Settlement, Stoddart & Poore 1287 (K); East side, Stoddart & Poore 1312 (K); Grand Anse, Fosberg 49691 (US, K); Settlement, Renvoize 1188 (US, K).

DACTYLOCTENIUM PILOSUM Stapf
S. l., Ridgway 90 (Fo); Veevers-Carter 90 (EA).

DAKNOPHOLIS BOIVINII (Camus) Clayt.
S. l., Veevers-Carter 29 (EA); Grand Anse, Fosberg 49696 (US, K); north of Settlement, Renvoize 1192 (US, K).

DIGITARIA HORIZONTALIS Willd.
North of Settlement, Stoddart & Poore 1290 (K); Grand Anse, Fosberg 49693 (US, K), 49703 (US, K).

DIGITARIA TIMORENSIS (Kunth) Bal.
S. l., Gwynne & Wood 1323 (EA); Ridgway 29 (Fo); Veevers-Carter 39 (EA); Settlement, Renvoize 1191 (US, K).

ENTEROPOGON SECHELLENSIS (Baker) Dur. & Schinz
S. l., Ridgway 30 (Fo); Veevers-Carter 30 (EA); in coconut plantation, Fosberg & Frazier 49747 (US, K); West side, Stoddart & Poore 1278 (K, US); Settlement, Renvoize 1193 (US, K).

ERAGROSTIS sp.
S. l., Fryer 4 (K), Fryer in 1908 (K); Ridgway 14 (Fo); Veevers-Carter 14 (EA); East side, Stoddart & Poore 1313 (K); Settlement, Renvoize 1200 (US, K).

ERIOCHLOA SUBULIFERA Stapf
Grand Anse, Fosberg 49735 (US, K); north of Settlement, Renvoize 1211 (K).

LEPTURUS REPENS R. Br.
S. l., Ridgway 98 (Fo); Veevers-Carter 98 (EA); Grand Anse, Fosberg 49694 (US, K); Settlement, Renvoize 1179 (US, K).

PANICUM MAXIMUM Jacq.
S. l., Ridgway 28 (Fo); Veevers-Carter 28 (EA); north of Settlement, Renvoize 1195 (US, K); Grand Anse, Fosberg 49689 (US).

PANICUM VOELTZKOWII Mez?
S. l., Ridgway 115 (Fo).

PENNISETUM POLYSTACHION (L.) Schultes
S. l., Ridgway 54 (Fo); Veevers-Carter 54 (EA).

SPOROBOLUS VIRGINICUS Kunth
S. l., Ridgway 2 (Fo); Veevers-Carter 2 (EA); Gwynne & Wood 1310 (EA); north of island, Stoddart & Poore 1288 (K); lagoon shore, back of Grand Anse, Fosberg 49743 (US, K); north of Settlement, Renvoize 1216 (US, K).

STENOTAPHRUM MICRANTHUM (Desv.) Hubb.
S. l., Ridgway 89 (Fo); Veevers-Carter 89 (EA); Settlement, Renvoize 1208 (US, K).

CYPERUS LIGULARIS L.
S. l., Ridgway 78 (Fo); Veevers-Carter 78 (EA); East side, Stoddart & Poore 1307 (K).

FIMBRISTYLIS CYMOSA R. Br.
S. l., Vesey-FitzGerald 5963d (K); Ridgway 33 (Fo); Veevers-Carter 33 (EA); Grand Anse, Fosberg 49695 (US, K); north of Settlement, Stoddart & Poore 1282 (K); Renvoize 1190 (US, K); lagoon beach, Renvoize 1214 (US, K).

COCOS NUCIFERA L.
Seen by Stoddart, 1968, Fosberg, 1968.

ASPARAGUS UMBELLULATUS Sieb.
S. l., Ridgway 112 (Fo); Veevers-Carter 112 (EA).

DRACAENA REFLEXA Lam.
Dupont records this from Astove acc. Hemsley (1919).

LOMATOPHYLLUM BORBONICUM Willd.
"...On the authority of Dupont, also [on] Astove..." Hemsley (1919). S. l., Ridgway 60 (Fo); Veevers-Carter 60 (EA); Grand Anse, Fosberg 49726 (US, K); West side, Stoddart & Poore 1270 (K); Gwynne & Wood 1295 (K, EA).

DIOSCOREA NESIOTIS Hemsl.
S. l., Ridgway 100 (Fo); Veevers-Carter 100 (EA); Grand Anse, Fosberg 49723 (US, K).

CASUARINA EQUISETIFOLIA L.
"Dupont records this from all the islands in his table..." Hemsley (1919); s. l., Ridgway 50 (Fo); Veevers-Carter 50 (EA).

FICUS NAUTARUM Baker
"Dupont records this species from all the islands in his tabular view" Hemsley (1919).

FICUS THONNINGII Bl.
"Dupont records this species from Astove..." (as F. aldabrensis) Hemsley (1919); s. l., Ridgway 117 (Fo), 97a (Fo); Veevers-Carter 58 (EA); Grand Anse, Fosberg 49733 (US, K).

FICUS sp. (aff. F. avi-avi)
S. l., Ridgway 97b (Fo); Veevers-Carter 97 (EA).

BOERHAVIA ELEGANS Choisy
S. l., Veevers-Carter 21 (EA); north of Settlement, Stoddart & Poore 1300 (K, US); Renvoize 1187 (US, K).

BOERHAVIA REPENS L.
"Dupont also records this on Astove" Hemsley (1919); s. l., Fryer 9 (K); Gwynne & Wood 1314 (K, EA); Ridgway 21 (Fo); Grand Anse, Fosberg 49702 (US), 49677 (US, K); north of Settlement, Stoddart & Poore 1294 (K, US).

PISONIA GRANDIS R. Br.
S. l., Gwynne & Wood 1300 (EA); Ridgway 86 (Fo); Veevers-Carter 86 (EA); Grand Anse, Fosberg 49683 (US, K).

ACHYRANTHES ASPERA L.
S. l., Gwynne & Wood 1317 (EA); Ridgway 41 (Fo); Veevers-Carter 41 (EA); north of Settlement, Stoddart & Poore 1284 (K); Renvoize 1198 (US, K); Grand Anse, Fosberg & Frazier 49748 (US, K); Fosberg 49707 (US, K), 49727 (US, K).

AMARANTHUS DUBIUS Mart. ex Thell.
S. l., Ridgway 73 (Fo); Veevers-Carter 73 (EA).

SESUVIUM PORTULACASTRUM (L.) L.
S. l., Gwynne & Wood 1318 (EA); Ridgway 77 (Fo); Veevers-Carter 77 (EA); lagoon shore back of Grand Anse, Fosberg 49745 (US); East side, Stoddart & Poore 1308 (K, US).

PORTULACA cf. AUSTRALIS Endl.
S. l., Thomasset 214 (K).

PORTULACA OLERACEA L.

S. l., Gwynne & Wood 1298 (EA); Ridgway 72 (Fo); Veevers-Carter 72 (EA); lagoon shore back of Grand Anse, Fosberg 49744 (US); in coconut plantation, Fosberg & Frazier 49756 (US); East side, Stoddart & Poore 1317 (K).

CASSYTHA FILIFORMIS L.

S. l., Ridgway 40 (Fo); Veevers-Carter 40 (EA); Grand Anse, Fosberg 49706 (US, K); north of Settlement, Stoddart & Poore 1289 (K); Renvoize 1186 (US, K).

HERNANDIA SONORA L.

S. l., Ridgway 82 (Fo); Veevers-Carter 82 (EA); Grand Anse, Fosberg 49686 (US, K).

CAPPARIS CARTILAGINEA Decne.

S. l., Gwynne & Wood 1291b (K, EA); Fryer 5 (K); Ridgway 53 (Fo); Veevers-Carter 53 (EA); Grand Anse, Fosberg 49718 (US, K); West side, Stoddart & Poore 1272 (K, US).

CLEOME STRIGOSA (Boj.) Oliv.

"Also Astove..." Hemsley (1919); s. l., Gwynne & Wood 1303 (EA); Fryer 10 (K); Ridgway 19a (Fo), 19b (Fo); Veevers-Carter 19a, b (EA); East side, Stoddart & Poore 1310 (K); Grand Anse, Fosberg 49676 (US, K); north of Settlement, Renvoize 1181 (US, K).

MAERUA TRIPHYLLA var. PUBESCENS (Kl.) DeWolf

S. l., Ridgway 23a (Fo), 23b (Fo), 23c (Fo), 113 (Fo); Veevers-Carter 23 (EA).

MORINGA OLEIFERA Lam.

S. l., Ridgway 75 (Fo); Veevers-Carter 75 (EA).

CAESALPINIA BONDUC (L.) Roxb.

Grand Anse, Fosberg 49678 (US).

CAESALPINIA MAJOR (Medic.) Dandy & Exell

S. l., Ridgway 44 (Fo); Veevers-Carter 44 (EA).

CASSIA OCCIDENTALIS L.

S. l., Ridgway 42 (Fo); Veevers-Carter 42 (EA); in coconut plantation, Fosberg & Frazier 49752 (US, K); West side, Stoddart & Poore 1274 (K, US); north of Settlement, Renvoize 1205 (US, K).

GAGNEBINA PTEROCARPA (Lam.) Baill.

S. l., Ridgway 12 (Fo); Veevers-Carter 12 (EA); West side, Stoddart & Poore 1268 (K).

SOPHORA TOMENTOSA L.

S. l., Ridgway 95 (Fo); Veevers-Carter 95 (EA).

TAMARINDUS INDICA L.
S. l., Ridgway 108 (Fo); Veevers-Carter 108 (EA).

TEPHROSIA PUMILA var. ALDABRENSIS (Drumm. & Hemsl.) Brumm.
S. l., Ridgway 99a (Fo), 99b (Fo); Veevers-Carter 99a, b (EA).

VIGNA UNGUICULATA subsp. DEKINDTIANA (Harms) Verdc.
S. l., Ridgway 46 (Fo); Veevers-Carter 46 (EA).

TRIBULUS CISTOIDES L.
S. l., Ridgway 51 (Fo); Veevers-Carter 51 (EA); Grand Anse, Fosberg 49690 (US, K).

SURIANA MARITIMA L.
S. l., Ridgway 76 (Fo); Veevers-Carter 76 (EA); lagoon shore back of Grand Anse, Fosberg 49741 (US, K); East side, Stoddart & Poore 1315 (K); north of Settlement, Stoddart & Poore 1292 (K, US); Settlement, Renvoize 1180 (US, K).

ACALYPHA CLAOXYLOIDES Hutch.
S. l., Thomasset 243 (K); Ridgway 111 (Fo); Veevers-Carter 111 (EA); Grand Anse, Fosberg 49730 (US).

ACALYPHA INDICA L.
S. l., Ridgway 94 (Fo); Veevers-Carter 94 (EA).

EUPHORBIA ABBOTTII Baker
"Dupont records this from all the islands of the Seychelles region except Gloriosa..." Hemsley (1919).

EUPHORBIA HIRTA L.
S. l., Ridgway 26 (Fo); Veevers-Carter 26 (EA); West side, Stoddart & Poore 1267 (K); north of Settlement, Renvoize 1197 (US, K).

EUPHORBIA sp. (near E. PROSTRATA Ait.)
S. l., Thomasset 232 (K); Ridgway 4 (Fo); Veevers-Carter 4, 17 (EA); East side, Stoddart & Poore 1306, 1311, 1319 (K); on coastal windswept sand, Vesey-FitzGerald 5963 (K); Grand Anse, Fosberg 49681 (US, K); north of Settlement, Renvoize 1182 (US, K).

PEDILANTHUS TITHYMALOIDES (L.) Poit.
S. l., Ridgway 62 (Fo); Veevers-Carter 62 (EA).

PHYLLANTHUS AMARUS Schum. & Thonn.
S. l., Ridgway 27 (Fo); Grand Anse, Fosberg 49712 (US); north of Settlement, Renvoize 1194 (US, K).

PHYLLANTHUS CHELONIPHORBE Hutchinson
S. l., Ridgway 58 (Fo); Grand Anse, Fosberg 49715 (US, K).

PHYLLANTHUS sp.
S. 1., Veevers-Carter 27 (EA).

PHYLLANTHUS MADERASPATENSIS L.
S. 1., Gwynne & Wood 1325 (EA); Ridgway 25 (Fo); north of Settlement, Renvoize 1196 (US, K); Grand Anse, Fosberg 49734 (US), 49701 (US, K), 49716 (US, K).

RICINUS COMMUNIS L.
S. 1., Ridgway 81a (Fo), 81b (Fo); Veevers-Carter 81a, b (EA); West side, Stoddart & Poore 1275 (K); Grand Anse, Fosberg 49698 (US, K, Fo, Mo, NY); north of Settlement, Renvoize 1199 (US, K).

MAYTENUS SENEGALENSIS (Lam.) Exell
S. 1., Gwynne & Wood 1302 (K, EA); Ridgway 32 (Fo); Veevers-Carter 32 (EA); lagoon shore back of Grand Anse, Fosberg 49740 (US, K); south of Grand Anse, Fosberg & McKenzie 49762 (US, K).

MYSTROXYLON AETHIOPICUM (Thunb.) Loes.
S. 1., Vesey-FitzGerald 5963d (K); Ridgway 105 (Fo); Veevers-Carter 105 (EA).

ALLOPHYLUS ALDABRICUS Radlk.
S. 1., Ridgway 93 (Fo); Veevers-Carter 25a, b, 93 (EA); north of Settlement, Renvoize 1206 (US, K); Grand Anse, Fosberg & Grubb 49729 (US, K), Fosberg & McKenzie 49761 (US).

COLUBRINA ASIATICA (L.) Brongn.
S. 1., Gwynne & Wood 1308 (K, EA); Ridgway 22 (Fo); Veevers-Carter 22 (EA); north of Settlement, Renvoize 1215 (US, K); Grand Anse, Fosberg 49684 (US, K); West side, Stoddart & Poore 1273 (K, US).

SCUTIA MYRTINA (Burm. f.) Kurz
S. 1., Gwynne & Wood 1294 (EA); Vesey-FitzGerald 5963c (K); Ridgway 16 (Fo), 106 (Fo); Veevers-Carter 106, 16 (EA); Grand Anse, Fosberg 49708 (US).

CORCHORUS AESTUANS L.
S. 1., Ridgway 36 (Fo); Veevers-Carter 36 (EA); Grand Anse, Fosberg 49692 (US), 49728 (US); north of Settlement, Renvoize 1202 (US, K).

GREWIA SALICIFOLIA Schinz
S. 1., Ridgway 15 (Fo); Veevers-Carter 15 (EA); Grand Anse, Fosberg 49751 (US, K).

TRIUMFETTA PROCUMBENS Forst.
S. 1., Ridgway 7 (Fo); Veevers-Carter 7 (EA).

ABUTILON ANGULATUM (G. & P.) Mast.
S. l., Thomasset 226 (K) "Thomasset's specimens are labelled Astove..." Hemsley (1919); s. l., Ridgway 56 (Fo); Veevers-Carter 56 (EA); Grand Anse, Fosberg 49737 (K, US).

GOSSYPIUM HIRSUTUM L.
S. l., Gwynne & Wood 1328 (K, EA); Ridgway 1 (Fo); Veevers-Carter 1 (EA); Grand Anse, Fosberg 49679 (US); West side, Stoddart & Poore 1277 (K, US); north of Settlement, Renvoize 1189 (US, K).

HIBISCUS ABELMOSCHUS L.
S. l., Ridgway 64 (Fo); Veevers-Carter 64 (EA).

HIBISCUS TILIACEUS L.
S. l., Ridgway 48 (Fo); Veevers-Carter 48 (EA); Grand Anse, Fosberg 49687 (US, K).

SIDA PARVIFOLIA DC.
S. l., Gwynne & Wood 1313 (EA); Ridgway 69 (Fo); Veevers-Carter 69 (EA); Grand Anse, Fosberg 49682 (US, K); East side, Stoddart & Poore 1320 (K).

SIDA "VESCOANA Baillon"
S. l., Vesey-FitzGerald 5962 (K) (probably only a variant of S. parvifolia).

THESPESIA POPULNEOIDES (Roxb.) Kostel.
S. l., Gwynne & Wood 1297 (EA); Ridgway 74 (Fo); Veevers-Carter 74 (EA); Grand Anse, Fosberg 49717 (US, K); West side, Stoddart & Poore 1269 (K); north of Settlement, Renvoize 1201 (US, K).

FLACOURTIA RAMONTCHII L'Herit.
S. l., Ridgway 114 (Fo).

TURNERA ULMIFOLIA L.
S. l., Ridgway 61 (Fo).

PASSIFLORA SUBEROSA L.
S. l., Ridgway 11 (Fo); Veevers-Carter 11 (EA); Grand Anse, Fosberg 49714 (US).

CUCUMIS PROPHETARUM ssp. DISSECTUS (Naud.) Jeffrey
S. l., Ridgway 34 (Fo); Veevers-Carter 34 (EA).

PEMPHIS ACIDULA Forst.
"Thomasset notes that this is also common in Astove..." Hemsley (1919); s. l., Ridgway 68 (Fo); Veevers-Carter 68 (EA); lagoon shore back of Grand Anse, Fosberg 49738 (US, K); East side, Stoddart & Poore 1316 (K); north of Settlement, Stoddart & Poore 1283 (K).

BRUGUIERA GYMNORHIZA (L.) Lam.
S. l., Ridgway 102 (Fo); Veevers-Carter 101 (EA).

RHIZOPHORA MUCRONATA Lam.
S. l., Ridgway 101 (Fo); Veevers-Carter 102 (EA); East side, Stoddart & Poore 1302 (K).

LUMNITZERA RACEMOSA Willd.
S. l., Ridgway 103 (Fo); Veevers-Carter 103 (EA); East side, Stoddart & Poore 1303 (K).

TERMINALIA CATAPPA L.
S. l., Ridgway 87 (Fo); Veevers-Carter 87 (EA).

TERMINALIA BOIVINII Tul.
S. l., Ridgway 107 (Fo); Veevers-Carter 107 (EA).

AZIMA TETRACANTHA Lam.
S. l., Ridgway 80 (Fo); Veevers-Carter 80 (EA); West side, Stoddart & Poore 1266 (K).

PLUMBAGO APHYLLA Boj. ex Boiss.
S. l., Gwynne & Wood 1290 (K, EA); Fryer 2 (K); Ridgway 18 (Fo); Veevers-Carter 18 (EA); Grand Anse, Fosberg 49710 (US, K); north of Settlement, Stoddart & Poore 1298 (K).

SIDEROXYLON INERME L. subsp. CRYPTOPHLEBIUM (Baker) J. H. Hemsley
S. l., Gwynne & Wood 1309 (EA); Ridgway 109 (Fo); Veevers-Carter 109 (EA); Grand Anse, Fosberg 49722 (US).

CATHARANTHUS ROSEUS (L.) Don
S. l., Gwynne & Wood 1327 (EA); Ridgway 52a (Fo), 52b (Fo); Veevers-Carter 52a, b (EA); Grand Anse, Fosberg 49680 (US, K); West side, Stoddart & Poore 1263 (K, US).

SARCOSTEMMA VIMINALE R. Br.
S. l., Gwynne & Wood 1293 (EA); Fryer 1 (K); Ridgway 13 (Fo); Veevers-Carter 13 (EA); Grand Anse, Fosberg 49709 (US, K); north of Settlement, Stoddart & Poore 1295 (K).

SECAMONE FRYERI Hemsl.
S. l., Gwynne & Wood 1296 (K, EA); Ridgway 70 (Fo), 116 (Fo); Veevers-Carter 70 (EA); Grand Anse, Fosberg 49721 (US, K).

EVOLVULUS ALSINOIDES L.
S. l., Fryer 8 (K); Ridgway 3 (Fo); Veevers-Carter 3 (EA); Grand Anse, Fosberg 49731 (US, K).

IPOMOEA BATATAS (L.) Lam.
S. l., Ridgway 65 (Fo); Veevers-Carter 65 (EA).

IPOMOEA PES-CAPRAE (L.) R. Br. (sens. lat.)
S. l., Fryer 11 (K); Ridgway 71A (Fo); Veevers-Carter 71A (EA); lagoon shore back of Grand Anse, Fosberg 49739 (US, K); north of Settlement, Stoddart & Poore 1291 (K); Settlement, Renvoize 1178 (US, K).

IPOMOEA TUBA (Schlecht.) Don
S. l., Ridgway 71b (Fo); Veevers-Carter 71b (EA); lagoon shore back of Grand Anse, Fosberg 49742 (US, K); lagoon coast, Gwynne & Wood 1307 (EA); East side, Stoddart & Poore 1304 (K); north of Settlement, Stoddart & Poore 1285 (K, US); Renvoize 1203 (K).

CORDIA SUBCORDATA Lam.
S. l., Gwynne & Wood 1301 (K, EA); Ridgway 66 (Fo); Veevers-Carter 66 (EA); West side, Stoddart & Poore 1281 (K, US); north of Settlement, Renvoize 1207 (US, K).

TOURNEFORTIA ARGENTEA L. f.
S. l., Ridgway 83 (Fo); Veevers-Carter 83 (EA); Grand Anse, Fosberg 49688 (US, K); East side, Stoddart & Poore 1314 (K).

AVICENNIA MARINA (Forsk.) Vierh.
"Dupont records this from Astove..." Hemsley (1919); s. l., Vesey-FitzGerald 5960 (K); Ridgway 67 (Fo); Veevers-Carter 67 (EA); in coconut plantation, Fosberg & Frazier 49758 (US, K).

CLERODENDRUM GLABRUM E. Mey. (C. minutiflorum Bak.)
S. l., Ridgway 110 (Fo); Veevers-Carter 110 (EA).

NESOGENES DUPONTII Hemsl.
S. l., Ridgway 104 (Fo); Veevers-Carter 104, 5, 113 (EA).

STACHYTARPHETA JAMAICENSIS (L.) Vahl
S. l., Ridgway 38a (Fo); Veevers-Carter 38 (EA); Grand Anse, Fosberg 49697 (US, K); north of Settlement, Stoddart & Poore 1293 (K); Renvoize 1184 (US, K); East side, Stoddart & Poore 1309 (K).

STACHYTARPHETA URTICIFOLIA Sims
S. l., Ridgway 38b (Fo); Grand Anse, Fosberg 49700 (US, K).

PREMNA OBTUSIFOLIA R. Br.
Southern part of coconut grove, Fosberg & Graham 49746 (US).

DATURA METEL L.
S. l., Ridgway 79 (Fo); Veevers-Carter 79 (EA); Grand Anse, Fosberg 49699 (US, K).

SOLANUM ALDABRENSE C. H. Wright
"Dupont records this from...Astove..." Hemsley (1919).

SOLANUM NIGRUM L.
S. l., Ridgway 49 (Fo); Veevers-Carter 49 (EA).

OCIMUM AMERICANUM L.

S. 1., Dupont 291 (K); Ridgway 43 (Fo); Veevers-Carter 43 (EA).

TABEBUIA PALLIDA (Lindl.) Miers

S. 1., Ridgway 63 (Fo); Veevers-Carter 63 (EA); West side, Stoddart & Poore 1280 (K, US).

ASYSTASIA BOJERIANA Nees

S. 1., Ridgway 5 (Fo), 24 (Fo); Veevers-Carter 24 (EA); Fryer 6 (K, 2 sheets); Gwynne & Wood 1315 (EA), 1324 (EA); north of Settlement, Stoddart & Poore 1296 (K, US); Renvoize 1183 (K, US); Grand Anse, Fosberg 49705 (US, K).

BARLERIA sp. (near B. DECAISNIANA Nees)

Reported from Astove by Hemsley on the basis of a Fryer specimen that cannot now be found at Kew (1919); s. 1., Ridgway 57 (Fo); Veevers-Carter 57 (EA); West side, Stoddart & Poore 1264 (K).

HYPOESTES ALDABRENSIS Baker

S. 1., Fryer 7 (K); Ridgway 91, 20 (Fo); Veevers-Carter 59, 91, 20 (EA); Grand Anse, Fosberg 49713 (US).

GUETTARDA SPECIOSA L.

S. 1., Gwynne & Wood 1321 (K, EA); Ridgway 85 (Fo); Veevers-Carter 85 (EA); Grand Anse, Fosberg 49685 (US, K); West side, Stoddart & Poore 1265 (K).

HEDYOTIS LANCIFOLIA Schum.

S. 1., Ridgway 55 (Fo); Veevers-Carter 55 (EA); Grand Anse, Fosberg 49724 (US, K).

HEDYOTIS sp.

S. 1., Ridgway 6 (Fo); Veevers-Carter 6 (EA); Gwynne & Wood 1326 (EA); Grand Anse, Fosberg 49753 (US, K); north of Settlement, Renvoize 1209 (US, K); sand dunes, Stoddart & Poore 1318 (US, K).

POLYSPHAERIA MULTIFLORA Hiern

S. 1., Ridgway 37 (Fo); Veevers-Carter 37 (EA); Grand Anse, Fosberg 49725 (US, K); south of Grand Anse, Fosberg & McKenzie 49760 (US).

TARENNA TRICHANTHA (Bak.) Brem.

S. 1., Ridgway 92 (Fo); Veevers-Carter 92, 35 (EA); Grand Anse, Fosberg 49720 (US, K); north of Settlement, Renvoize 1204 (US, K).

SCAEVOLA TACCADA (Gaertn.) Roxb.

S. 1., Ridgway 84 (Fo); Veevers-Carter 84 (EA); in coconut plantation, Fosberg & Frazier 49757 (US).

BIDENS PILOSA L.

S. 1., Ridgway 96 (Fo); Veevers-Carter 96 (EA); in coconut plantation, Fosberg & Frazier 49750 (US, K).

LAUNAEA INTYBACEA (Jacq.) P. Beauv.
S. 1., Gwynne & Wood 1316 (K, EA); Ridgway 47 (Fo); Veevers-Carter 47 (EA); in coconut plantation, Fosberg & Frazier 49749 (US); north of Settlement, Stoddart & Poore 1299 (K); Renvoize 1213 (US, K).

LAUNAEA SARMENTOSA (Willd.) Alst.
S. 1., Ridgway 88 (Fo); Veevers-Carter 88 (EA).

VERNONIA ALDABRENSIS Hemsl.
S. 1., Vesey-FitzGerald 5963b (K); Gwynne & Wood 1292 (K, EA); Ridgway 9 (Fo); Veevers-Carter 9 (EA); Grand Anse, Fosberg 49719 (US, K); West side, Stoddart & Poore 1271 (K); north of Settlement, Stoddart & Poore 1297 (K); Renvoize 1185 (US, K); East side, Stoddart & Poore 1305 (K).

VERNONIA CINEREA (L.) Less.
S. 1., Ridgway 10 (Fo); Veevers-Carter 10 (EA); in coconut plantation, Fosberg & Frazier 49754 (US, K); south of Grand Anse, Fosberg & McKenzie 49759 (US); West side, Stoddart & Poore 1276 (K, US); north of Settlement, Stoddart & Poore 1301; Renvoize 1210 (US, K).

10. NOTE ON THE LEPIDOPTERA OF ASTOVE ATOLL

J. F. G. Lionnet

Writing in 1911, J. C. F. Fryer, who had visited Astove as a member of the 1908 Percy Sladen Trust Expedition to the Indian Ocean, stated: "The time I spent on Astove was insufficient to properly investigate its structure and therefore the flora and fauna were quite neglected"; and "insects were very numerous and it was a matter of great regret that few could be taken; butterflies were more common than on any other island and comprised one species, the beautiful *Precis rhadama*, not noted elsewhere".

On 8 March 1967 the writer spent five hours on the west coast of Astove, at Grand Anse, which he devoted to collecting butterflies. These appeared to be as numerous as at the time of Fryer's visit. As, with the exception of Fryer and the writer, none of the collectors who have visited the Aldabra group of islands (Assumption, Cosmoledo and Astove), including W. L. Abbott in 1892, A. Voeltzkow in 1902, E. G. B. Meade-Waldo in 1905, C. Prola in 1953, G. Cherbonnier in 1959 and H. Legrand in 1956 and 1959, visited Astove, it is thought desirable to publish a list of the species already recorded on the atoll. It is, however, hardly necessary to point out that this list could certainly be improved by a more thorough investigation. Thus the Royal Society party which visited Astove in 1968 collected *Acraea ranavalona*, *Acraea terpsichore legrandi*, *Junonia clelia epiclelia*, *Colotis evanthides*, *Syntarucus pirithous* (= *telicanus*) and the hesperiid *Pelopidas mathias* Fabr., which is a new record for the atoll (pers. comm., Dr T. G. Howarth, British Museum (Natural History) and the account in Bayne and others (1970)).

NOCTUIDAE

Bryophilopsis nesta (Bainbrigge Fletcher)	Collected by Lionnet
Tarache malgassica (Mabille)	Collected by Fryer

PIERIDAE

Belenois aldabrensis (Holland)	Collected by Fryer
Belenois grandidieri form *voeltzkowi* (Karsch) (see Bernardi 1954)	Collected by Lionnet
Colotis evanthides (Holland)	Collected by Lionnet

DANAIDAE

Danaus chrysippus (Linnaeus)	Collected by Lionnet

Atoll Research Bulletin No. 136: pp. 113 - 114, 1970.

ACRAEIDAE

Acraea ranavalona Boisduval	Collected by Lionnet
Acraea terpsichore legrandi Carcasson	Collected by Lionnet

NYMPHALIDAE

Junonia rhadama (Boisduval)	Collected by Fryer and noted by Lionnet
Junonia clelia epiclelia (Boisduval)	Collected by Fryer and Lionnet
Phalanta phalantha aethiopica (Rothschild and Jordan)	Collected by Lionnet

Fryer also reported that he had noticed Colotis (Teracolus) pernotatus (Butler), a synonym of C. etrida (Boisduval), on Astove. However, since according to Legrand Fryer mistook Colotis evanthides (Holland) on Aldabra for the former species, this record is doubtful.

Acknowledgements

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11. LAND (INCLUDING SHORE) BIRDS OF ASTOVE

C. W. Benson

Introduction

Much detail concerning the birds of Astove, especially on the systematics of *Cisticola cherina* and *Nectarinia sovimanga*, has already been given in the paper on land birds of Cosmoledo (Benson 1970), and need not be repeated. The same acknowledgements and other introductory remarks also apply. Excepting a brief reference by Abbott to a rail (see below), the first mention of birds traced is by Dupont (1907), who drew up a list of species as a whole. Fryer (1911, 428) makes a brief reference, remarking that birds seemed scarce. Vesey-FitzGerald (1940, 486-488) includes Astove in his account of land birds of the Aldabra archipelago, as does Hartman (1958), who spent 9 December 1957 there. H. M. S. Owen called at Astove on 16 March 1964, and a few observations are given by Bourne (1966). I. S. C. Parker collected specimens for the National Museum of Kenya on 7 October 1967, the day after his visit to Menai Island, Cosmoledo. I have had the loan of his specimens, as for Menai. A. W. Diamond, P. Grubb and I were on the western arm of Astove from about 1100 hours until after sunset on 5 March 1968. Their observations, and a few from J. Frazier, have considerably augmented my own. Some further observations were made by M. E. D. Poore and D. R. Stoddart on both the east and west sides of Astove on 15 September 1968.

Resident true land birds

Dryolimnas cuvieri — White-throated Rail

As for Cosmoledo, recorded at second-hand by Abbott (in Ridgway 1895, 529), and listed by Dupont (1907). Fryer (1911, 428, under *D. abbotti*?) also records it. There is no subsequent record. Due to human activity, it is unlikely that it could still exist there.

Streptopelia picturata — Malagasy Turtledove

This species is listed by Dupont (1907), but no other reference to its occurrence has been traced. As on Cosmoledo (with the possible exception of South Island), it has evidently been extirpated, assuming that it really did formerly occur.

Cisticola cherina — Malagasy Grass-Warbler

Vesey-FitzGerald (1940, 488) found it "abundant", Hartman (1958) "common". Diamond and I also found it common, more so even than the sunbird. Diamond and Stoddart noted the same call as on Cosmoledo.

As already recorded in the Cosmoledo account, a female collected contained a much enlarged egg. Also, as discussed therein, C. cherina appears to be of recent origin on both Cosmoledo and Astove, and except for some tendency to smaller size on Wizard, is still undifferentiated from the Malagasy parent stock.

Corvus albus — Pied Crow

Listed by Dupont (1907, as C. scapulatus), though Vesey-FitzGerald (1940, 488) thought it was only a visitor. Hartman (1958) saw one pair. I saw one couple and one single bird. As on Cosmoledo, the population is evidently extremely small.

Zosterops maderaspatana — Malagasy White-eye

Vesey-FitzGerald (1940, 488) records it as common, though Hartman (1958) did not see it. Diamond saw 15 in all, and I saw a few others. It would appear to be less common than both the grass-warbler and the sunbird. Diamond noted that the call was the same as on Aldabra, though stronger. This is perhaps to be expected, since Astove birds are larger (Benson 1969). A male collected on 5 March 1968 had testes measuring 6 x 4, 7 x 5 mm, a female the same day had a yolking egg of diameter 6 mm. In order of predominance (numbers of individual specimens in each group), the stomach contents of these specimens were:

Lepidoptera: larvae
Hemiptera: Homoptera
Coleoptera: Curculionidae
Arachnida: small spiders
Psocoptera
Hymenoptera: winged ants

In one specimen there were in addition the apparent remains of a seed and some petals.

Astove birds are considered by Benson (1969) inseparable from those of Z. m. maderaspatana from the moister parts of Malagasy, and lack the yellow tone above of Gloriosa birds. The latter can be matched with material of Z. m. maderaspatana from the drier parts of Malagasy, in the southwest and the extreme north. Aldabra (though not Cosmoledo) birds also tend to be yellowish above.

Nectarinia sovimanga — Souimanga Sunbird

This species is listed by Dupont (1907, as Cinnyris abbotti), while Fryer (1911, 428) noted a Cinnyris. It is also recorded by Vesey-FitzGerald (1940, 488) and by Hartman (1958, as Cinnyris comorensis), the latter giving it as "common". Bourne (1966) records "Anjouan Sunbirds" (sic) as "common". We also found it to be common. As already explained in the Cosmoledo account, the population of Astove is inseparable from N. s. buchenorum. The misconception that it might be referable to N. comorensis, of Anjouan, in the Comoros, arose from the male and female collected by Vesey-FitzGerald (1940) and identified in the British Museum as "near Cinnyris comorensis Peters". These specimens cannot now be found, but are virtually certainly N. s. buchenorum. As explained by

Benson (1967, 86), N. comorensis is a distinct species, albeit derived from sovimanga. No reasonable doubt whatever can now remain but that comorensis is endemic to Anjouan.

Vesey-FitzGerald describes a nest, apparently unoccupied, placed 1.3 m above the ground in a bush of Pemphis acidula. I found a similar old nest in a bush of Suriana maritima. It was collected, and is in the British Museum (Natural History). S. A. Renvoize has pointed out that both these plants are spray-zone species. On Aldabra there are some casualties among sunbirds' nests due to spray. There was certainly some breeding on Astove at the time of our visit, since a female collected contained a yolking egg measuring 7 x 8 mm, while three males had enlarged testes, in one case both measuring 7 x 5 mm. A female collected by Parker also had enlarged gonads. One of two females collected by myself, with wing 49, tail 33, culmen from base 16.5 mm, cannot be fully grown (see measurements in the Cosmoledo account, Benson 1970), and is probably only about six weeks old (from date of hatching). It may thus be presumed to have been from an egg laid in January. The stomach-contents of two males and two females collected by Parker were insect fragments, including Coleoptera. In order of predominance (numbers of individual specimens in each group), those of three males and four females collected by myself were:

Arachnida: small spiders
Hemiptera: Homoptera
Psocoptera
Hymenoptera: ants
Hymenoptera: Parasitica

Diamond heard the same cat-like "miaaw" call as can be heard on Aldabra. Frazier thought that, although the birds were tame, they were less so than on Aldabra. On Astove, in general, they would be more liable to human disturbance.

Possibly resident shore birds

Ardea cinerea — Grey Heron

Listed by Dupont (1907). We saw at least two in the lagoon in March 1968. Adults and young were seen in June 1969 by Diamond and Frazier, so this bird is probably resident.

Egretta garzetta — Little Egret

At least two white and three dark phase birds were seen. Diamond recorded a disused nest in a Bruguiera bush on an island in the entrance to the lagoon. As for Cosmoledo, there is no evidence of the "large flocks" recorded by Dawson (1966, 7).

According to Loustau-Lalanne (1963, 22), "Demiegretta sacra =(asha)" ... "occurs and breeds only on Astove island". On page 13 he also mentions Egretta garzetta as occurring on Astove, stating that it is snow-white. No mention of any colour phase is made, though he states

(page 14) that _D. asha_ is "a dimorphic bird, white or grey in colour". Dawson (1966, 7) goes still further, and apparently considers that there are no fewer than three species of egret on Astove, i.e. _E. dimorpha_, _E. garzetta_ and _D. asha_. According to Watson et al. (1963, 101, 106), _D. sacra_ occurs no nearer to Astove than the Cocos-Keeling Islands, and _D. asha_ the Laccadives (merely one record). The latter is placed by Grant and Mackworth-Praed (1933, 194) as a synonym of _D. schistacea_. This name is a possible source of still further complication. Forbes-Watson (1966) states that he has seen Reef Herons _E. schistacea_ breeding alongside Little Egrets _E. garzetta_ at Tananarive, Malagasy, and gives sight records from the African coast to as far south as Pemba Island. However, White (1965, 25) may be correct in regarding _schistacea_ as a yellow-billed subspecies of _E. garzetta_, and its breeding range may not extend south of the equator, accordingly excluding any likelihood of it breeding in Malagasy. _E. g. schistacea_ is not mentioned in the comprehensive account of a heronry at Tananarive by Malzy (1967).

Apart from the three species of Ardeidae treated under the headings above and below, there is at present no satisfactory evidence of the occurrence of any species anywhere in the Aldabra archipelago in addition to _Egretta garzetta_, the subspecies according to Benson (1967, 68) being _E. g. dimorpha_. Two specimens of this subspecies were recently collected on Cosmoledo. Contrary to Loustau-Lalanne, there are two colour phases. Benson (1967, 96) suggests that _E. alba_, which breeds in the Comoros, might occasionally occur. But there is still no evidence of this.

Bubulcus ibis Cattle-Egret

Bourne (1966) records six around the settlement, and six were seen in the settlement itself by Stoddart and Poore in September 1968. Diamond, Frazier and I each saw one bird in March 1968. Frazier's bird was in a coconut tree.

Butorides striatus Little Green Heron

Listed by Dupont (1907, as _B. atricapillus_). Diamond saw two in the lagoon, and one in a plantation. On Aldabra, too, this species is not strictly confined to coasts. On Astove as well as on Cosmoledo the subspecies is most likely _B. s. crawfordi_.

Migrants

Dupont (1907) lists the same eight species from Astove as for Cosmoledo. The only further records are the following, from Diamond, Grubb or myself, from the shore of the lagoon unless otherwise stated (those asterisked are not listed by Dupont): *_Squatarola squatarola_, three; _Charadrius leschenaultii_, at least three; _Numenius phaeopus_, about ten; _Arenaria interpres_, about 100; *_Crocethia alba_, two; *_Erolia testacea_, about 100; _Dromas ardeola_, at least 30. In addition, Grubb saw what is thought to have been a _Charadrius mongolus_ (Penny, in press).

No true land bird migrants have as yet been recorded from Astove, but as for Cosmoledo there must be occasional occurrences.

Summary

1. An account is given of the land (including shore) birds of Astove.

2. The true land birds are very similar to those of Cosmoledo (Benson 1970), and there is the same paucity of species in comparison to Aldabra. The rail *Dryolimnas cuvieri* and turtledove *Streptopelia picturata*, which at one time are said to have occurred, are probably extinct. The warbler *Cisticola cherina* and sunbird *Nectarinia sovimanga*, similar to those of Cosmoledo, are plentiful. The white-eye *Zosterops maderaspatana*, specimens of which are the same as those from the more humid parts of Malagasy, is not so plentiful.

3. Unlike Cosmoledo, there is no evidence that any species has been introduced by man.

4. There are four possibly resident herons or egrets (family Ardeidae), though the status of the Cattle Egret *Bubulcus ibis* in particular requires further investigation. It has been claimed that the three species *Egretta dimorpha*, *E. garzetta* and *Demiegretta asha* all occur. But probably there is only the one, *E. garzetta* (subspecies *dimorpha*), present in a white phase and a dark phase.

5. Of migrants, twelve species of shore birds which breed in the Palaearctic Region have been recorded; also the Crab-Plover *Dromas ardeola*. No land bird migrants have as yet been recorded.

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12. ECOLOGICAL CHANGE AND EFFECTS OF PHOSPHATE MINING ON ASSUMPTION ISLAND

D. R. Stoddart, C. W. Benson, and J. F. Peake

Introduction

Because of their rugged terrain and lack of surface water, elevated reef-limestone islands are often unsuitable for human settlement. As a result of greater environmental diversity and possible greater age than the sand cays of sea-level coral atolls, such islands frequently possess larger and more diverse faunas and floras. Yet because many possess large resources of phosphate derived from bird guano, they have often been subjected to a degree of human interference uncommon on isolated islands before the development of airfields and similar installations. Examples of elevated reef islands where such major modification has taken place include Makatea in the east Pacific, Nauru, Niue and Ocean in the central Pacific, and Christmas in the eastern Indian Ocean.

The results of massive mining disturbance on island ecology are of interest, since they may provide a guide to the results of other kinds of major habitat disturbance, including the construction of airfields and military bases. Such construction work involves the clearing of native vegetation and destruction of habitats, and also the preparation of new habitats for colonisation by introduced plants and animals. We know little of the long-term resilience of indigenous biotas on islands, including those subject to such major interference, except that changes involving extinction are irreversible (Stoddart 1968a, 1968b, MacArthur and Wilson 1967, Mayr 1965).

Assumption Island, 27 km southeast of Aldabra, provides an example of the ecological effects of surface phosphate mining over the last sixty years (Baker 1963). With a fauna and flora similar to those of Aldabra, though smaller, before mining began, it provides data on the capacity of plants and animals to survive vegetation clearance and human settlement, and on the invasions and colonisations which have taken place since settlement began. Assumption was visited by a party from the Royal Society Expedition to Aldabra on 15-16 September 1967, and this paper records the observations made and compares them with previous accounts, mostly from pre-mining times. Familiarity with the fauna and flora of Aldabra meant that maximum advantage could be taken of this short visit.

Apart from hydrographic surveys in 1823 and 1878, Assumption was first visited by W. L. Abbott, who collected birds, plants and insects

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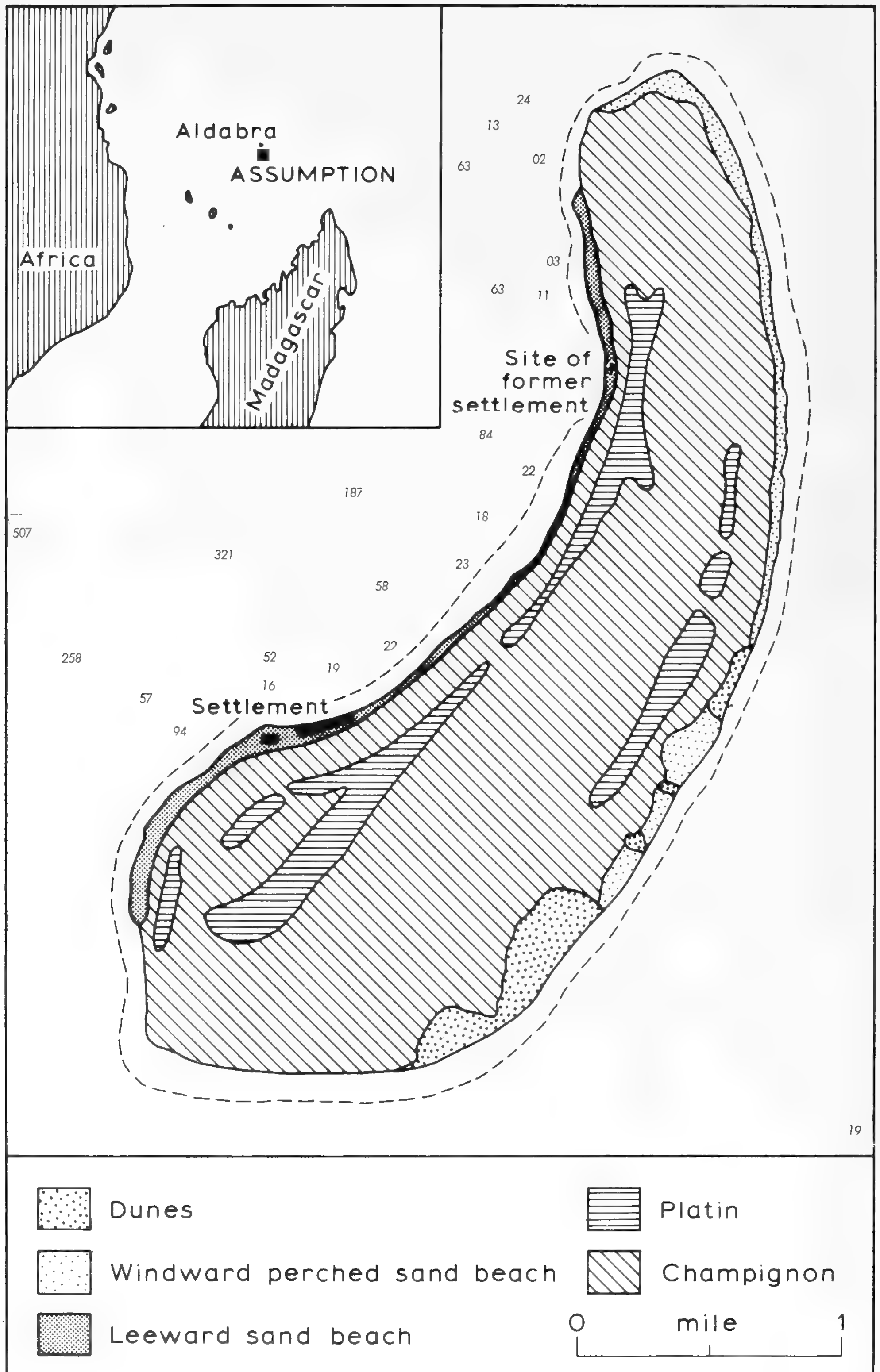

Fig. 6. Assumption

in September 1892. The ornithologist M. J. Nicoll spent 12-13 March there, and was followed by R. Dupont (birds, insects, plants), 19-21 September 1906, and by J. C. F. Fryer (geology, general observations, insects), 6-13 September 1908. The island was uninhabited until June 1908, when a guano-mining settlement was established on the northwest coast: the observations of these earlier workers thus recorded the pre-mining state of the island biota. Table 12 lists these and later

Table 12. Scientific Studies at Assumption Island

Date	Study	Reference
1756 Aug. 15	Nicholas de Morphey, general	Horsburgh (1809)
1823	Richard Owen, hydrographic survey	Adm.Ch.718(1878)
1878	W. J. L. Wharton, hydrographic survey	Adm.Ch.718(1879)
1892 Sept.	W. L. Abbott, birds	Abbott (1893), Ridgway (1895)
1901 Oct. 13	H. A'C. Bergne, general	Bergne (1901)
1906 March 12-13	M. J. Nicoll, birds	Nicoll (1906, 1908)
1906 Sept. 19-21	R. Dupont, birds, insects, plants	Dupont (1907)
1908 Sept. 6-13	J. C. F. Fryer, geology, insects	Fryer (1911)
1910	R. Dupont, insects, plants	
1916	R. Dupont, plants	Hemsley (1919)
1937	L. D. E. F. Vesey-FitzGerald vegetation, birds	Vesey-FitzGerald (1941, 1942)
1956	H. Legrand, Lepidoptera	Legrand (1965)
1956	W. Travis, underwater observations	Travis (1959)
1959	H. Legrand, M. Gerber, Lepidoptera	Legrand (1965)
1960 Oct. 13-16	B. H. Baker (geology) and C. J. Piggott (soils)	Baker (1963), Piggott (1961, 1968)
1964	H.M.S. Owen, Cdr D. W. Haslam: survey, birds	Bourne (1966)
1964	R. E. Honegger, birds, reptiles	Honegger (1966)
1964 Nov. 10	Bristol Seychelles Expedition: M. J. Penny, M. Penny, R. Gaymer and others, birds	This report
1965 Oct. 3	R. Gaymer, birds	This report
1967 March	J. F. G. Lionnet, H. A. Beamish, insects; H. A. Hirth, turtles	
1967 Sept. 15-16	Royal Society party: D. R. Stoddart (geomorphology, plants), C. W. Benson (birds), J. F. Peake (land invertebrates), J. H. Price (marine algae), J. M. Boyd, E. N. Wright (birds)	This report
1967 Oct. 8	M. D. Gwynne, D. Wood, I. S. C. Parker, plants and birds	Fosberg and Renvoize (1970), Parker (1970)
1968 July 31	Royal Society party: J. Frazier R. Hughes, J. Gamble, R. Lowery	

scientific investigations. The Royal Society party in September 1967 consisted of D. R. Stoddart (geomorphology, plants), C. W. Benson (birds), J. F. Peake (land invertebrates), J. H. Price (marine algae), J. Morton Boyd, and E. N. Wright (birds). A further Royal Society party, comprising R. Lowery, J. Gamble, J. Frazier and R. Hughes, made a brief visit on 31 July 1968.

Topography

Assumption (Figure 6) is a raised reef-limestone island, probably similar in origin to Aldabra but without a central lagoon. It is 6 km long, northeast to southwest, and 0.6 to 1.6 km wide, with an area of 10.5 sq km (compare the land area of Aldabra, 155 sq km). The limestone rises to a maximum height of about 6 m above sea-level, and forms cliffs along the northern half of the east coast. As on the south coast of Aldabra, the cliffs are topped by a perched beach up to 1.8 m thick and 18 m wide, which at the head of small coves develops into low dunes 3-4.5 m thick. The perched beach approaches close to the cliff-top along the central part of the coast, but moves inland towards the north, revealing a cliff-top platform of pinnacled limestone. The cliffs are undercut only in coves, and when facing seaward are more ramp-like; they overlook a rock-cut abrasion platform 90-200 m wide (Plates 20 and 21). This platform lacks growing corals, and towards its outer edge has in places mushroom residuals of a surface at least 0.6 m higher (Plate 22). Several high dunes, their steeper slope facing inland, are found along the southeast coast; their heights range from 14-28 m above sea-level. The smaller high dunes have a simple outline, but the larger ones are cut by valleys on their seaward side and may be eroding. Most of the west coast consists of a narrow sand-flat with low dunes, banked against a previously eroded cliff-line. The coast below both the high dunes and the western sand-flat is formed by a wide sand beach.

The main body of the island consists of a deeply-pitted and eroded champignon, with tidal solution holes up to 6 m deep and generally steep-sided. Round the margins of the island there is a higher rim with a less dissected and much smoother surface standing 1.2-1.8 m above the champignon. This surface may be compared to the pavé of Astove, and to the surface of the Aldabra 8 m ridge, where undissected, rather than to typical Aldabra platin. Baker (1963, 101) suggests that the slabby limestone associated with this smoother surface is formed from lithified carbonate sands. Phosphates have accumulated both on the surface, where large quantities have now been scraped away, and in the solution holes, many of which are larger below ground than at the surface. More information on mining activities would be needed before attempting an explanation of the present surface topography on Assumption.

Piggott (1961, 1968) divides the soils of Assumption into three types: phosphatic Desnoeufs Series on the limestones, now largely dug for phosphate; Farquhar Series on the dunes; and variable Shioya Series especially on the leeward sand flat.

Climate

Rainfall records have been maintained at the Settlement since November 1964. The total fall for 1965 was 813 mm, for 1966 920.5 mm, and for 1967 (to 16 September only) 724.1 mm (Table 13). Rainfall is concentrated from December to March, but is rather variable from year to year. September and October are almost rainless. Several heavy falls have occurred during the period of record: 51.3 mm on 15 April 1965, 105.9 mm on 17 January 1966, 102.6 mm on 5 March 1966, 59.2 mm on 29 April 1966, 113.8 mm on 30 April 1966, and 81.3 mm on 14 December 1966. In 1966 the heavy falls on the four days mentioned accounted for 42 per cent of the total annual rainfall. As at Aldabra the period of the Southeast Trades (June-November) is the dry season, that of the north-westerlies and calms (December-May) the wet season. No temperature records have been kept.

Vegetation

The vegetation of Assumption can be described, based on brief reconnaissance only, in terms of eight communities:

1. perched beach community
2. high dune community
3. *Pemphis* community of the cliffs
4. west coast sand beach community
5. mixed scrub community of the champignon
6. herbs and grasses community of the pavé or platin
7. solution-hole community
8. settlement vegetation

Perched beach community (Plate 23)

The narrow zone of sand perched on top of the seaward cliffs along the east coast closely resembles that on the south coast of Aldabra, except that the cliff-line is more irregular. The beach is subject to constant spray during the Trades and to wave-swash at exceptional tides. As a result areas on the seaward side of the perched beach lack vegetation cover. The vegetation consists of a mosaic of discrete areas of *Sporobolus virginicus* and *Sclerodactylon macrostachyum*, bounded sharply inland by a transition to the rock-surface cover of *Sarcostemma viminale* and *Plumbago aphylla*. The dominant *Sporobolus* turf is much denser and longer (up to 230 mm) than at Aldabra, where it is close-cropped by tortoises. Few other plants are present: small patches of *Stenotaphrum clavigerum*, inconspicuous individuals of *Launaea sarmentosa* and *Sida parvifolia*, and infrequent shrubs only where small dunes have developed.

Table 13. Monthly rainfall at Assumption[1]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1964											26.67	47.75	
1965	151.64	44.96	92.71	170.94	46.48	60.71	31.50	47.50	3.81	6.35	70.61	86.36	813.56
1966	204.72	59.18	192.28	198.88	32.77	20.07	18.29	9.91	13.46	-	19.81	151.13	920.50
1967	136.40	184.91	93.98	136.91	14.61	11.94	46.74	59.20	1.27[2]				

Source: Settlement Manager, Assumption

1. Figures in mm converted from inches and tenths

2. To 16 September only

High dune community (Plates 24-27)

The high dunes of the southeast coast have a comparatively gentle but irregular seaward slope and a steep landward slope. Vegetation on the seaward slope is variable, some areas being dominated by grasses (Sporobolus virginicus and Sclerodactylon macrostachyum), others with shrubs, but the characteristic features of this community are the large areas of bare and sometimes mobile sand. In the areas dominated by grass species the density of the vegetation is frequently so low that large areas of bare sand are visible. The dominant shrubs are low wind-trimmed Scaevola taccada and bushy Suriana maritima, with occasional Tournefortia argentea. The ground under the shrubs, and the walls and floors of the transverse valleys, are largely bare, with clumps of Fimbristylis cymosa and scattered Euphorbia indica 30-60 cm tall. On the crest and backslope of the dunes, Tournefortia is the dominant shrub, with Fimbristylis and patches of Portulaca sp. and Sida parvifolia. At the foot of the high dunes on the seaward side there is a narrow sand flat with Suriana and Tournefortia, and a ground cover of Ipomoea pes-caprae extending onto the beach. In the sheltered area immediately landward of the high dunes there is a fleshy mat of Portulaca oleracea and a narrow belt of stunted Thespesia populneoides woodland. Some of the shrubs on the dunes are overgrown with Cassytha filiformis, and on isolated lower dunes to the north Tournefortia and Scaevola bushes are so heavily overgrown that they are almost invisible.

Cliffs

Cliffs lacking a perched or sea-level sand beach occur at the northern end of the island, where there is a small clump of Pemphis acidula. Thomasset (in Hemsley 1919) noted Pemphis as "common", but Fryer (1911, 433) found only "a few trees...near the west coast...(which) do not unite to form bush". Dupont (1907) mapped Pemphis near its present position. The present distribution is clearly a small relic of a more extensive cover, though with the absence of suitable habitat probably less extensive than on Aldabra.

West coast sand beach community (Plates 28 and 29)

This has certainly been much altered by man, especially on the sites of the present and former settlements. Shrubs are common along this sand strip, species including Scaevola taccada, Suriana maritima and Tournefortia argentea along the shore, and Clerodendron glabrum 3-5 m tall a short distance inland. Sophora tomentosa is present but not common. In the north, near the old settlement, there are some rather bushy trees of Cordia subcordata, which were in flower in September 1967. The ground cover between the shrubs largely consists of a thick carpet of Cassytha filiformis, with Pennisetum polystachion, Amaranthus viridis and Melanthera biflora. Canavalia rosea is an escape from cultivation near the former settlement. The sand-strip vegetation thus consists of a mixture of native and introduced species.

Mixed scrub community

The mixed scrub on the elevated limestone has clearly been much altered by man, and now presents such a diverse form that any generalisations are difficult to make. Before mining began it was probably comparable to the more open mixed scrub areas of Aldabra. Abbott (1893, 763) noted that the surface was "not so densely covered with scrub as Aldabra", while Nicoll (1908, 107) found it "less thickly covered than Gloriosa. The central part is almost bare of vegetation, the only growth being a few low bushes (hibiscus [Thespesia?]), and a thin wiry grass which springs from the cracks and fissures in the coral". Fryer (1911,433) stated that "the vegetation over the majority of the island consists of a tangled network of Plumbago (P. aphylla sp.?), Astephanus (A. arenarius sp.?) and numerous low bushes not identified. Small trees such as Euphorbia Abbotti, banyan (Ficus sp.?) were not uncommon, while Dracaena (D. reflexa sp.?) occurred in guano-filled pits".

From the floristic records of Dupont (1907) and Hemsley (1919), it appears that the scrub consisted of Thespesia populneoides, Guettarda speciosa, Pisonia grandis, Euphorbia abbottii, Ficus nautarum, Ficus aldabrensis and Dracaena reflexa, with a ground cover of Colubrina asiatica, Lomatophyllum borbonicum, Solanum aldabrense, Capparis cartilaginea, grasses, sedges and herbs. A number of common characteristic trees or shrubs of the Aldabra mixed scrub have, however, not been recorded on Assumption, and were not seen in 1967: these include the trees Grewia salicifolia, Ochna ciliata, Vernonia aldabrensis, Terminalia boivinii, and Tricalysia cuneifolia, and the shrubs Mystroxylon aethiopicum, Sideroxylon inerme, Maytenus senegalensis, Tarenna supra-axillaris, Apodytes dimidiata and Ehretia cymosa. Some may have been present in former times but were not collected and are perhaps now extinct on Assumption.

Guano-mining led to large-scale vegetation clearance. Vesey-FitzGerald reported in 1937 that "the central area ... has been largely cleared of vegetation. ... A thick secondary mat of Plumbago now covers the whole of this country" (Vesey-FitzGerald 1942, 12). There are now very few trees or tall shrubs on the champignon. In the south there are small trees of Euphorbia abbottii, and in holes some bushy Ficus nautarum, but few other shrubs are taller than 2 m, and then only towards the south. Between the settlement and the high dunes the central part of the island is dominated by Gossypium hirsutum with a thick ground cover of Plumbago aphylla and Sarcostemma viminale. Shrubs collected in this sector include Clerodenrum glabrum (1.6 m), Acalypha claoxyloides (1-1.3 m), Abutilon fruticosum (1 m), Secamone fryeri (0.6-1 m), and Capparis cartilaginea. Ficus aldabrensis and Guettarda speciosa, noted by Dupont, were not seen in 1967, and the latter may be extinct on the island; only one almost leafless Pisonia grandis was seen near the northwest coast (Plate 30).

In contrast to the poverty of the shrub layer, the ground vegetation is diverse, but patchy. Apart from Plumbago, Sarcostemma and Cassytha, it includes the grasses Dactyloctenium pilosum, Enteropogon sechellensis and Eriochloa meyeriana, and such weedy plants as Achyranthes aspera, Boerhavia elegans, Euphorbia hirta, Ipomoea tuba, Nesogenes dupontii, Passiflora foetida, Passiflora suberosa, and Tribulus cistoides. Momordica charantia is an escape from cultivation. Solanum aldabrense and the introduced grass Panicum maximum were not seen in 1967, and both Capparis and Lomatophyllum are uncommon. Close to the settlement the mixed scrub is being invaded by such common weeds as Stachytarpheta jamaicensis and Catharanthus roseus. Dried Nostoc commune was taken from bare rock pavement in the centre of the island. In general the vegetation is so low over the southern part of Assumption that visibility is limited more by the irregularity of the ground than by the height of shrubs and trees.

The patchiness of the vegetation needs to be stressed, as a result of the colonisation of workings of different ages. There is a mosaic of plant communities varying in their structure, age and species composition; these differences can possibly be associated with periods of human activity. Shrubs are usually found on the small areas that have escaped such activity, on in areas of older workings.

Pavé or platin community (Plate 31)

The northern part of the island has a much less dissected surface and lacks shrubby growth. Along the seaward side it is covered with a dense mat of Plumbago and Sarcostemma, but further inland and towards the north large areas of ground are bare, except for scattered grasses and sedges (Dactyloctenium, Fimbristylis), weeds such as Achyranthes, and long trailers of orange vine Cassytha filiformis. In crevices and holes it is possible to find a few flowering Hedyotis sp. and Sida parvifolia, characteristic on Aldabra of the most exposed and almost unvegetated champignon of the southeast coast. This area has probably been worked over for phosphate, and the vegetation may be a pioneer one of the bare rock pavement which has resulted.

Solution-hole community

Solution holes in the champignon now contain the largest trees on Assumption, apart from coconuts and Casuarina. In the centre and south of the island Ficus nautarum is characteristic of solution holes, as on Aldabra: Dracaena reflexa, said to occur in holes by Fryer, was not seen by us. No ferns have previously been recorded from Assumption, though Acrostichum aureum is common in shallow holes at the east end of Aldabra. Shrivelled Acrostichum was found in several holes at the north end of Assumption in 1967, together with, in one case, a fern not then recorded but since found on Aldabra, Nephrolepis biserrata (Plate 32).

One hole near the north point also contains several tall trees of Ceriops tagal, though no mangroves have been previously recorded from Assumption and they do not occur on the coast. Local informants stated that this was the only solution hole with mangroves. In Fryer's manuscript journal (Fryer 1908), however, he records several such pits with mature mangroves up to 12 m tall, mostly Bruguiera though in one case with Ceriops. He was unable to understand how mangroves came to colonise such inland holes, at least half a mile from the sea, and thought they were formerly more extensive. Most of these inland mangroves have probably disappeared through being cut for timber since 1908. One hole north of the settlement is now used as a pool for keeping captive turtles.

Settlement vegetation

Before permanent settlement there were "a few casuarina trees, and in one spot on the shore three coconut palms" on the west coast (Nicoll 1908, 107); Sebert Baty in 1895 had found a total of six coconut palms (Bergne 1900). At the site of the first settlement (Plate 33), northern part of the west shore, there is a clump of tall Casuarina, a coconut, two massive trees of Terminalia catappa, a patch of Caesalpinia bonduc, and spreading out over the bare platin behind the beach a conspicuous area of Agave. At the present settlement there is a woodland of mature Casuarina near the manager's house, with, to the south, a coconut plantation of several hundred trees. At the settlement itself there are cultivated trees (Moringa oleifera, Carica papaya) and other plants (Catharanthus roseus, Datura metel, Gossypium hirsutum, Ipomoea batatas, Leonotis nepetifolia, Momordica charantia, Pedilanthus tithymaloides, Solanum lycopersicum and Solanum nigrum), together with weeds (Achyranthes aspera, Boerhavia elegans, Cleome strigosa, Dactyloctenium aegyptium, Enteropogon sechellensis, Hypoestes aldabrensis, Stachytarpheta jamaicensis, Vernonia cinerea). Between the settlement and the sea there is a narrow hedge of Scaevola taccada, with some Tournefortia argentea and Suriana maritima, and a ground cover of Canavalia rosea. Two introductions mentioned by Dupont in 1907 were not seen in 1967: Abrus precatorius and Albizia fastigiata.

Flora

The flora of Assumption has never been properly worked up from the earlier collections, though Dupont (1907) published a list of species in his table of island plants, and Hemsley (1919) included species collected by Fryer, Fox, Dupont and Thomasset in his "Flora of Aldabra". Gwynne and Wood (1969) record 8 species, four of them sight records. A list of plants collected in 1967 is given in a later paper by Fosberg and Renvoize (1970), and the flora is being included in the revision of the Aldabra flora now being undertaken.

The publications of Dupont and Hemsley list about 63 species from Assumption; with the collections made in 1967, this is increased to about 100, or roughly half the number of species found on Aldabra. Among the species conspicuously absent from the earlier records are the mangroves (species of *Avicennia*, *Bruguiera*, *Rhizophora*, *Lumnitzera*, *Sonneratia*, *Ceriops* and *Xylocarpus*, all found on Aldabra), *Pandanus*, and the ferns; one mangrove and two ferns have since been collected. Of the additional species collected in 1967, perhaps 16 represent indigenous species present but uncollected at the time of the earlier visits (e.g. species of *Acalypha*, *Acrostichum*, *Boerhavia*, *Ceriops*, *Dactyloctenium*, *Euphorbia*, *Ipomoea*, *Launaea*, *Nephrolepis*, *Nostoc*, *Pennisetum*, *Portulaca*, *Sida*, *Sophora*, *Sclerodactylon*). At least 19 species collected in 1967, or one-fifth of the known flora, represent deliberate introductions or weeds which have probably arrived since settlement began in 1908; six of these have also appeared at Aldabra. These introduced plants include species of *Agave*, *Carica*, *Catharanthus*, *Datura*, *Ipomoea*, *Leonotis*, *Momordica*, *Moringa*, *Solanum* and *Terminalia*.

Some idea of the contrast between the floras of Aldabra and Assumption, and the greater changes in the latter, can be obtained by comparing the collections made sixty years ago on each with those made in 1966-67 (this comparison includes only Stoddart's collections and not the more extensive collections made on Aldabra by Fosberg and Renvoize):

	Aldabra	Assumption
Per cent total flora recorded by Hemsley and earlier workers	46	28
Per cent recorded by both Hemsley and in present collection	38	35
Per cent recorded only in present collection (new records)	16	36
Total number of species	c.200	c.100

The comparison is only approximate, for the Assumption flora is still to be properly collected and the Aldabra collections of 1966-67 were small and preliminary, but it is clear that considerable changes have taken place in the flora as well as in the vegetation of Assumption since settlement began.

Of the species listed by Hemsley (1919), three have been described as endemic (*Panicum assumptionis* Stapf, *Eriochloa subulifera* Stapf, *Stenotaphrum clavigerum* Stapf), and twenty could be classed as "regional endemics". Since the new records are mainly cosmopolitan weeds and cultivated plants, the flora is changing from one typical of the elevated reef islands of the southwest Indian Ocean to one dominated by common tropical species of no particular regional affinity.

Marine fauna

The Green Turtle Chelonia mydas was formerly abundant on Assumption. Baty (in Bergne 1900) and Nicoll (1908) reported them in great numbers close to the shore, and also nesting. Fryer found them plentiful, but said that it was no longer possible to take up to two hundred in a night as had once been the practice (Fryer 1910, 263). Numbers have declined catastrophically, and though turtle still come ashore at one or two places on the east coast to lay, for several years it has had to be prohibited to take them or their eggs anywhere on Assumption. There has, however, been no means of enforcing this prohibition among the island's labourers. Little else is known of the marine fauna; J. L. B. Smith collected fish at Assumption in 1954, and a few records have appeared in his revisions of the Indian Ocean fish fauna (Smith 1955a, 1955b, 1956a, 1956b).

Land fauna other than birds

The only indigenous mammal at Assumption is an insectivorous bat Taphozous mauritianus collected by Fryer in October 1908 (Scott 1914, 163). The fruit-bat Pteropus, found on Aldabra, is absent. The indigenous land reptiles formerly included the Giant Land Tortoise Geochelone sp., which, however, became extinct before ever being recorded alive, as far as can be ascertained. Fryer found the remains of two in a solution hole in 1908, and Honegger found eggs in a guano pit on 1964. The geckos Phelsuma abbotti abbotti and Hemidactylus mercatorius, and the skink Ablepharus boutonii, are also indigenous (Boulenger 1911); both Hemidactylus and Ablepharus were collected on the high dunes in 1967. All three species are found on Aldabra. The land Crustacea include Birgus latro, very common in 1906 (Nicoll 1908, 112) and still existing. 65 species of insects have been recorded, mainly collected by Fryer and Dupont, and the literature on these earlier collections is keyed in Table 14. There was no opportunity to collect insects in 1967, though members of the Odonata were conspicuous. Blackman and Pinhey (1967) review this group on western Indian Ocean islands, with mention of Assumption.

Land (including shore) birds

Birds form the best known element in the Assumption land fauna, and are also the group apparently most affected by guano mining. In connection with the following account, we are grateful to Professor Charles G. Sibley and Mrs Eleanor H. Stickney for the loan from the Peabody Museum of Natural History, Yale University, of material collected by Hartman in 1957.

Table 14. Insects recorded from Assumption by the Percy Sladen Expedition

Group	Number of species	Reference
Orthoptera	10	Bolivar (1912, 1924)
Dermaptera	1	Burr (1910)
Hemiptera	4	Distant (1913, 1917)
Lepidoptera	22	Fletcher (1910), Fryer (1912), Hampson (1908)
Coleoptera	8	Aurivillius (1922), Champion (1914), Gebien 1922, Scott (1912, 1926)
Hymenoptera	8	Cockerell (1912), Morley (1912), Turner (1911)
Diptera	3	Lamb (1922, 1914), Scott (1914)
Odonata	6	Campion (1913)

Residents

There are five land birds which breed (or did so formerly) on Assumption, with four more which may do so. These are:

Dryolimnas cuvieri	White-throated Rail
Streptopelia picturata	Malagasy Turtledove
Centropus toulou	Malagasy Coucal
Nectarinia sovimanga	Souimanga Sunbird
Corvus albus	Pied Crow

plus

Ardea cinerea	Grey Heron
Egretta garzetta	Little Egret
Bubulcus ibis	Cattle Egret
Butorides striatus	Little Green Heron

All of these species also breed on Aldabra, which has at least seventeen breeding land birds. The following breeding Aldabra land birds have never been recorded on Assumption:

Threskiornis aethiopica	Sacred Ibis
Falco newtoni	Malagasy Kestrel
Alectroenas sganzini	Comoro Blue Pigeon
Caprimulgus madagascariensis	Malagasy Nightjar
Hypsipetes madagascariensis	Malagasy Bulbul
Nesillas aldabranus	Aldabra Tsikirity
Dicrurus aldabranus	Aldabra Drongo
Zosterops maderaspatana	Malagasy White-eye
Foudia eminentissima	Red-headed Forest Fody

Nor has the Barn Owl Tyto alba been recorded from Assumption. It certainly occurred (and probably bred) in the past on Aldabra, but appears no longer to exist there. The Malagasy Cisticola cherina, which Benson found plentiful on Menai and Wizard Islands (Cosmoledo Atoll) and on Astove in March 1968, is unkown on Assumption or Aldabra.

The Assumption subspecies of the White-throated Rail was discovered by Abbott in 1892 and named Dryolimnas abbotti by Ridgway (1894a, 74). Fryer (in MS) in 1908 found "plenty of the Rail D. abbotti which was very tame and very common". Both Abbott in 1892 and Nicoll in 1906 found it abundant. "They were found on all parts of the island, except on the summit of the sandy hill on the windward side" (Nicoll 1908, 109). In spite of the large numbers, Nicoll feared that introduced rats might lead to its extinction by predation of eggs (1908, 111). It did duly become extinct some time between the establishment of the settlement in 1908 and Vesey-FitzGerald's visit in 1937, undoubtedly as a result of catching for food, destruction of habitat, and predation by introduced cats and rats. It was conspecific with Dryolimnas c. cuvieri, of Malagasy, as is the Aldabra form. It appears not to have lost the power of flight so completely as D. c. aldabranus: see the wing-lengths in Benson (1967, 74).

The turtledove Streptopelia picturata was not definitely recorded by Abbott in 1892 (see Ridgway 1895, 522, under Turtur aldabranus), but was so by Nicoll (1906, 693; 1908, 109, under T. assumptionis). It was "quite common" and "extraordinarily tame" at the time of Nicoll's visit, when it nested in the branches of Hibiscus (?) bushes. It was mentioned by Fryer in 1908, but not by Vesey-FitzGerald in 1937, and has not been seen since. It was probably extirpated by the labourers, again for food. It seems to have only differed from the Aldabra population in being a little larger (Benson 1967, 75-79). This is supported by wing-lengths of recent Aldabra material, four males measuring 166, 167, 169, 170, and six females 155, 157, 158, 160, 160, 163 mm.

The coucal Centropus toulou was collected by Abbott (C. insularis in Ridgway 1895, 522-523), and was noted as common and tame by Nicoll (1906, 494, as C. assumptionis) and by Fryer (in MS). Vesey-FitzGerald (1940, 487) saw one in 1937. But it is not mentioned by Hartman (1958), neither did Gaymer see it in 1964 or 1965, nor Benson in 1967, nor Frazier in 1968. Wright in 1967 thought he saw one but was not sure. It may also be extinct, extirpated by the labourers for food. According to Benson (1967, 80-81), it is (or was) only possibly distinguishable from C. t. insularis of Aldabra by its slightly shorter tail. The following are measurements in mm of further adult Aldabra specimens:

	Wing	Tail
♂♂	149 150	232 243
♀	165	250

The smaller male tail-length indicates an overlap in figures for insularis and assumptionis, and the latter name is really no longer worth maintaining.

The sunbird Nectarinia sovimanga is still relatively flourishing, in no apparent immediate danger of extinction, even though its numbers have probably been greatly reduced by destruction of the original habitat. On the morning of 16 September Benson counted eight males, four females and six unsexed birds on the south-east side of the island, in the mixed scrub community, and in the afternoon 43 males and 26 females in the west coast sand beach community, also a few in Casuarina trees at the site of the old settlement near the northwest corner of the island. Frazier found sunbirds singing in the trees at the present settlement. All males observed appeared to be in full breeding dress. Feeding was noticed at flowers of Agave and Tournefortia argentea. Although Vesey-FitzGerald (1940, 487) reported it as rare, Hartman (1958) found it common, and it is the most plentiful true land bird on Aldabra. It is possible that competition from Nectarinia has excluded the white-eye Zosterops maderaspatana from Assumption, which, unlike Aldabra, may not be large enough for both (Serventy 1951). Nevertheless both have been recorded from other small islands--Gloriosa, Astove, and Menai Island in Cosmoledo. N. s. abbotti is a valid subspecies, endemic to Assumption (Benson 1967, 84-86). This is confirmed by further material from Aldabra, Assumption, Cosmoledo and Astove, the subspecies on both the latter two islands being N. s. buchenorum.

The crow Corvus albus was collected by Abbott in 1892 (Ridgway 1895, 532, under C. scapulatus). Nicoll (1906, 693; 1908, 109) recorded small numbers, and found several empty nests "built at the tops of the tallest trees on the island". He also noted it as "extremely wild". Vesey-FitzGerald (1940, 588), however, considered it was only a visitor. "About 25" were seen in 1964 (Bourne 1966); and Gaymer recorded about "two dozen" in the same year. Benson saw 10 on 15 September 1967 and Morton Boyd a total of 15 on the same day: it was seen at the settlement, in Casuarina trees at the old settlement site, and over the southeast dunes. Frazier saw none in 1968. Probably it does still breed on Assumption, as recently definitely established for Aldabra. Breeding may take place only at infrequent intervals, and so can be easily overlooked.

Of the possibly breeding shore birds, Ardea cinerea and Egretta garzetta, both collected by Nicoll (1906, 695-696, the latter under Demiegretta sacra), have not otherwise been recorded, except that Dupont (1907) lists the former. Possibly they no longer exist on Assumption, though it is unlikely that they have been molested to the same extent (except at possible breeding sites) as the turtledove and coucal discussed above. Bubulcus ibis was seen by Gaymer in 1964, and there was a flock of about 60 inland, just south of the settlement, in 1967. Its status on Assumption is quite uncertain.

Butorides striatus, recorded by Nicoll (1906, 696, under B. crawfordi), and listed by Dupont (1907, under B. atricapillus), was seen by Gaymer in 1964, by Benson on the southeast shore at low water (three adults, one immature) and inland (three adults) in 1967, and by Frazier on the southwest coast in 1968. Assumption is the type-locality of

Nicoll's *B. s. crawfordi*, only otherwise recorded from Aldabra (Benson (1967, 67). Additional material, now in the British Museum (Natural History), is available from Aldabra, and A. D. Forbes-Watson has kindly donated on behalf of the National Museum of Kenya, Nairobi, a specimen collected by I. S. C. Parker in the Amirante Islands, on the reef between Darros and St Joseph (5°25'S, 53°18'E), on 23 September 1967. Wing-lengths in mm of this material are:

Aldabra	♂♂	159	165	
	♀♀	156	158	162
Amirante Islands	♀	169		

One male and one female from Aldabra have the sides of the neck, chest and abdomen washed with brown, but the other specimens lack this wash. It may be that only the latter are completely adult, the difference thus being due to age rather than sex, *contra* Benson (1967, 68). It is impossible to separate the Amirante specimen from those from Aldabra on colour, and on present evidence *crawfordi* must be regarded as extending north to the Amirantes. Possibly Amirante birds are a little larger, see also further figures in Benson (1967). This is also suggested by weights, the Amirante specimen being the heaviest. Those whose wing-lengths were given above weighed respectively 164, 158, 168, 163, 177, 180 g. This recent Aldabra material, collected in 1968, is not markedly paler grey below than in any specimen of *B. s. rhizophorae*, whether collected a decade or a century ago, and the two subspecies may only be distinguishable on size. It would seem that the type of *crawfordi* and the adult male from Aldabra examined by Benson (1967, 67), so pale grey below, are exceptional individuals.

Migrants

The following are recorded from Assumption:

Ardeola idae

One seen by Benson to fly onto the island, from the direction of Aldabra, at 0800 hours on 16 September 1967. It was thought to be this species, now known to occur on Aldabra, whereas *A. ralloides* is not.

Squatarola squatarola

Two seen on the southeast coast in 1967.

Charadrius leschenaultii

Listed by Dupont (1907, under *Aegialitis geoffroyi*); three seen in 1967.

Numenius phaeopus

Listed by Dupont (1907); two seen in 1967.

Numenius arquata

Listed by Dupont (1907).

Tringa nebularia

Listed by Dupont (1907, under *Totanus glottis*); two seen in 1967.

Actitis hypoleucos

Listed by Dupont (1907).

Arenaria interpres

Listed by Dupont (1907); 100 seen in March 1964 (Bourne 1966); five seen in 1967.

Crocethia alba

One seen in 1967.

Erolia minuta

Listed by Dupont (1907).

Dromas ardeola

Listed by Dupont (1907); 40 seen in March 1964 (Bourne 1966); one seen on the southeast shore in 1967.

Hirundo rustica

On 13 December 1957 Hartman (1958) saw "an unidentified swallow, black above, white below, and with a long, forked tail", "in flight over the sand dunes". It was very probably this species, for which Benson (1967, 95) quotes one sighting for Malagasy in January, while a number were seen on Aldabra in March 1968.

Other migrants must occur occasionally on Assumption. Thus among shore birds, Erolia testacea is plentiful on Aldabra, and some 14 species of palaearctic true land birds have by now been found there.

Sea birds

Sea birds were not common in 1967, and have certainly greatly decreased in numbers during the last sixty years. It is probable that few now nest on Assumption. The following species have been recorded:

Phaethon rubricauda

Collected by Abbott (Ridgway 1895, 522), who found it breeding in dense thickets or under a bush, and by Nicoll (1906, 693). Not seen in 1967. Loustau-Lalanne (1963, 21, 23) considers it confined to Assumption, but this is not correct. Thus Benson (1967, 99) quotes records from Aldabra, where it breeds. P. lepturus has never been recorded from Assumption.

Sula abbotti

Collected by Abbott (Ridgway 1893, 599; 1895, 520-522), who stated that "a few" breed. According to Fryer (1911, 433) it "inhabits the large dune, never descending to low parts of the island." It has not been recorded since, and Vesey-FitzGerald (1941, 52) says it was extirpated in 1926; the species now only breeds on Christmas Island (Indian Ocean). Gibson-Hill (1950) has very fully discussed uncertainties in the earlier records. The two specimens collected by Fryer on Assumption, and examined by Gibson-Hill, are still extant in the University Museum of Zoology, Cambridge. The statement by Loustau-Lalanne (1963, 23) in regard to the Red-footed Booby Sula sula is presumed to be really intended to apply to S. abbotti, though unfortunately it is more than "very near extinction" on Assumption.

Sula dactylatra (syn. S. cyanops)

Noted by Abbott (Ridgway 1895, 520) to breed on bare ground on the sand dunes; collected by Nicoll (1906, 697). Probably no longer breeding in 1937 (Vesey-FitzGerald 1941, 521) but "a few" seen in 1964

(Bourne 1966). Not seen in 1967. Sebert Baty in 1895 found a "camp of boobies", species not specified, on guano 600 yards northeast of the big dune, and boobies in trees (Sula sula ?) all over the island (Bergne 1900).

Sula sula

Recorded breeding by Nicoll (1906, 697). Four seen in 1967.

Fregata minor (syn. F. aquila)

Recorded by Nicoll (1906, 692) and listed by Dupont (1907). Not seen in 1967, but R. Hughes saw a female in March 1968.

Fregata ariel

A group of four males and seven females, all apparently adult, seen soaring over the southeast coast in 1967.

Sterna fuscata

15-20 seen by J. Frazier off the west coast in March 1968.

Sterna albifrons

Listed by Dupont (1907, under both S. minuta and S. balaenarum). About thirty probably this species seen in March 1964 (Bourne 1966).

Sterna sumatrana

Three recorded in March 1964 (Bourne 1966), and one flock of ten, another of four, on the southeast coast in 1967.

Thalasseus bergii

Listed by Dupont (1907, under both "Sterna Bersteini" and "Sterna Bergi").

Anous stolidus

Listed by Dupont (1907).

Gygis alba

Collected by Nicoll (1906, 696), listed by Dupont (1907). One seen in March 1964 (Bourne 1966). On 16 September 1967 Benson saw one lot of ten, four each of two, and one single bird, and E. Wright a total of about 20. J. F. Peake found three probably breeding in a solution hole. Frazier saw 4-5 off the west coast on 31 July 1968.

Introduced animals

Rats were abundant by the time of Nicoll's visit (before settlement began), and were already destroying birds' eggs. Goats were introduced "many years" before Abbott's visit in 1893, according to him from Europa Island in the Mozambique Channel (Abbott 1893, 763). According to Bergne (1901) goats were introduced by H.M.S. Wasp, Captain Bidenfield, in 1867, a crew member on that occasion living on Astove when Bergne visited it in 1901. Sebert Baty gave the number of goats as 300-400 in 1895 (Bergne 1900). Dupont (1907, 12) gave the date of introduction as c. 1887 and the number in 1906 as "several thousands". Nicoll (1908, 112) found twenty, very wild, near the foot of the dunes. Vesey-FitzGerald (1942) did not mention them and Gaymer thought they were extinct in 1964. We saw none in 1967, though we were told that some still existed in the north. Dupont was so impressed by the goats as a food resource that he suggested the introduction of rabbits and hares (Dupont 1907, 13). Dogs, cats and chickens were seen in 1967.

Settlement and Exploitation

Settlement began in June 1908, and by Fryer's arrival in September tracks had been cut through the bush in several directions. The first settlement was in the northern part of the west bay, and large rainwater tanks were constructed there in 1910. Both contained excellent water in 1967. At a date unknown the settlement was transferred to the south end of the bay, where there is now a manager's house and garden, and a line of labourers' huts (Plate 34). There is a short jetty, a boat house, and to the north a small cemetery. On the east coast there are two small fishing shacks on the dunes.

Between 1926 and 1945, 161,000 tons of guano were exported, together with an unknown amount before 1926. After 1945 the lease lapsed and exploitation ceased in 1948; but with the renewal of the lease in 1955 mining began again. A mechanical crusher and light railway (Plate 35) have been installed. Baker (1963) estimated reserves at 160,000 tons following his survey in 1960, mostly in solution holes. Because of the sharp decline in the price of guano, production was at a standstill in 1967, and mounds of guano stood at the settlement unable to be shipped. Assumption is leased jointly with Aldabra and Cosmoledo by Mr H. Savy of Mahé, for thirty years from 1955 (Stoddart and Wright 1967, 48-50). Unlike Aldabra, it still forms part of the Colony of Seychelles, and has not been incorporated in the British Indian Ocean Territory.

Summary and Conclusions

After sixty years of intensive exploitation and a previous century of more casual interference, Assumption has now lost many of the faunal and floral elements which formerly characterised the elevated reef islands of the southwest Indian Ocean. There is no doubt that at the time of settlement in 1908 a number of irreversible changes had taken place, particularly the disappearance of the Giant Land Tortoise. The Tortoise population on so small an island must clearly have been more vulnerable to cropping for food during the late eighteenth and early nineteenth centuries than on the much larger island of Aldabra. The presence of introduced goats must have initiated vegetation changes, and early reports mention the wide distribution of Plumbago.

Major vegetation and floristic changes, however, followed the beginning of phosphate mining, in which vegetation was removed and the phosphate scraped from the surface of the ground, leaving a sterile rock surface for new colonisation. Many of the species common in Mixed Scrub on Aldabra and possibly formerly present on Assumption appear now to be absent on the latter, and their place has been taken by weeds such as Plumbago, Sarcostemma and Cassytha, and escapes such as Gossypium. All of these species are rare on Aldabra except close to the settlement where man has actively interfered with indigenous vegetation. The only areas apparently unaffected by these changes on Assumption are the high

dunes and the windward perched beach, with their typical vegetation of Sporobolus, Sclerodactylon, Scaevola, Suriana and Tournefortia, all characteristic of similar habitats on Aldabra. Lack of active disturbance and the extreme environmental conditions have probably restricted invasions in these habitats. In the flora as a whole, indigenous elements are possibly being replaced by common weeds, many of pan-tropical distribution, and cultivated plants, but further data on these processes are required.

With major vegetation changes and probable continuous predation, the bird fauna has changed considerably since 1908. The endemic rail Dryolimnas cuvieri abbotti has certainly become extinct, the local population of the turtledove Streptopelia picturata possibly so too. Of the shore birds, Ardea cinerea and Egretta garzetta may no longer occur. Changes in the sea bird population have been considerable. Though a few Sula sula and S. dactylatra have been seen in recent years, the booby breeding colonies over the northern half of the island have disappeared. Abbott's Booby Sula abbotti is now extinct on Assumption, and breeds only on faraway Christmas Island. None of the other eight recorded species of sea bird is now definitely known to breed, though Gygis alba probably does so. On the other hand, the endemic sunbird Nectarinia sovimanga abbotti, the crow Corvus albus, and migrants generally, are probably little affected by changes on the island.

Since settlement began the large breeding grounds on Assumption of the Green Turtle have been largely abandoned, and though this decline appears to be common throughout the southwest Indian Ocean it has been especially catastrophic on Assumption.

Assumption thus provides an extreme example of ecological change brought about by human settlement and exploitation. Since exploitation depends on the maintenance of an economic price for phosphate, it is possible that the venture will become uneconomic and the settlement could be abandoned. If this occurs it will be useful to observe the progress of ecological change in the future, as part of the Royal Society's continuing programme at Aldabra.

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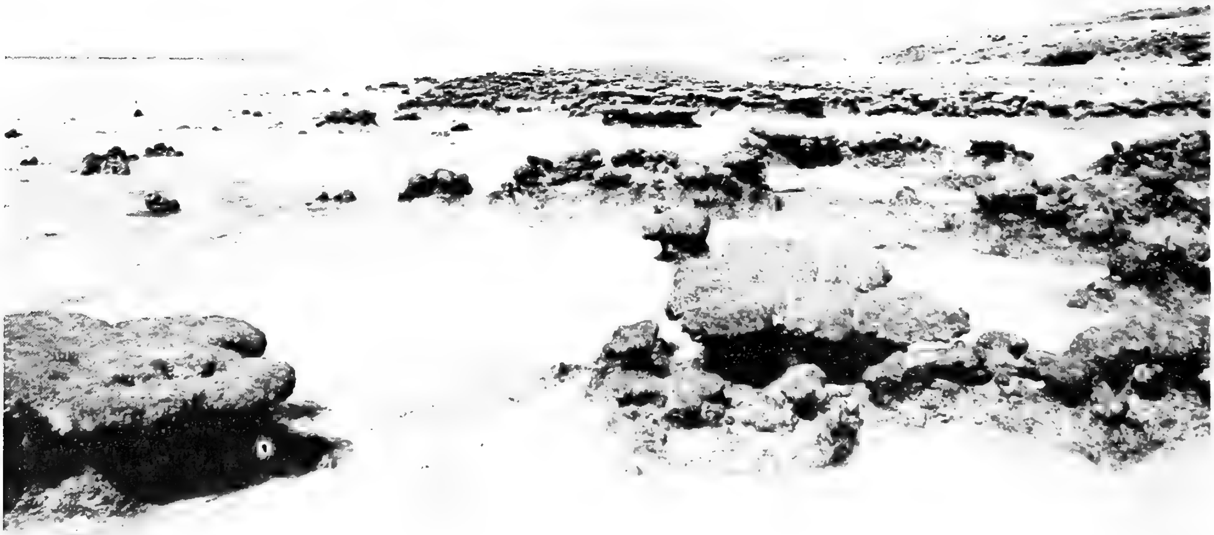
18. Low champignon cliffs and perched beach, east coast, view towards the south

19. Pocket beach in the champignon cliffs, continuous with the higher perched beach; north of the high dunes, east coast

20. Eroded inner edge of the reef flat where it passes beneath the beach at the foot of the high dunes, east coast

21. Transverse erosional grooves in the reef flat, backed by a rocky erosion ramp, beach, and high dunes; east coast



22. Outer edge of the reef flat near the high dunes, east coast

23. Small dunes on the perched beach, which is densely covered with grasses; east coast, looking north

24. Clumps of <u>Suriana maritima</u> and scattered <u>Fimbristylis</u> on the eroding seaward face of the highest dune

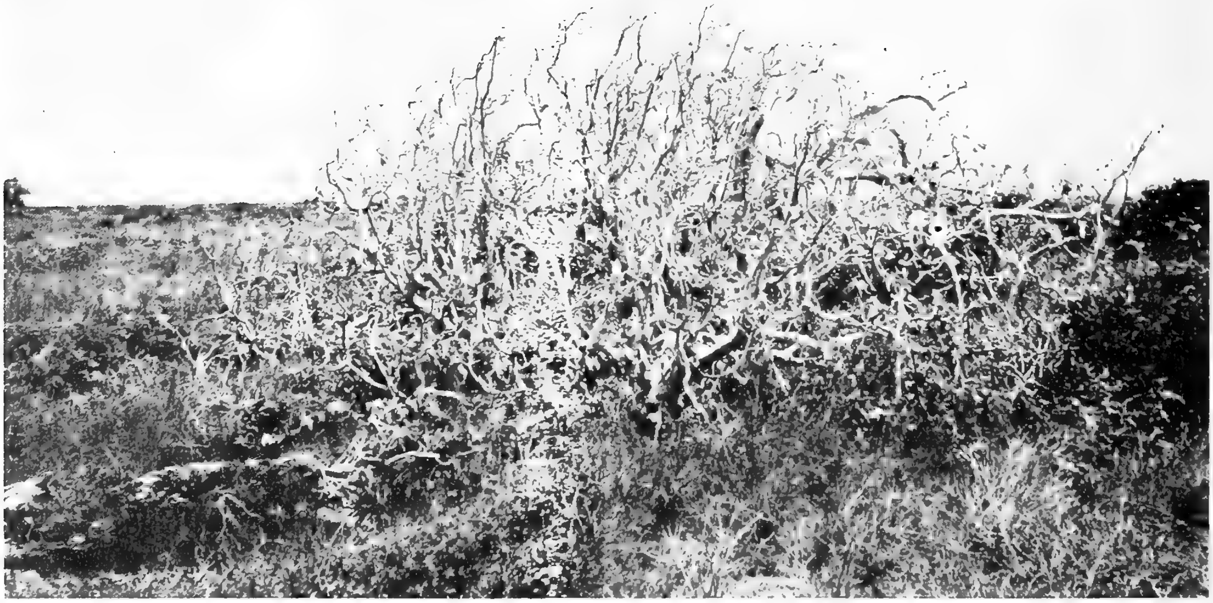
25. <u>Scaevola</u> and <u>Fimbristylis</u> on the high dunes

26. View from the summit of the highest dune, with Tournefortia scrub, across the low mixed scrub of the centre of Assumption. The line of Casuarina trees on the west shore marks the Settlement

27. The lee slope of the highest dune, with Tournefortia and Scaevola

28. Tournefortia and Suriana forming the littoral hedge on the prograding west coast, view north from Settlement

29. Suriana and Pemphis forming the littoral hedge near the northern end of the west coast



30. Leafless Pisonia in the low mixed scrub in the centre of the island

31. Flat platin almost devoid of soil and vegetation, northern end of the island; Ficus in the foreground

32. Nephrolepis biserrata in a solution hole, north end

33. Agave, massive Terminalia, and Cocos at the site of the old settlement; note the water tank behind the coconut

34. Labourers' huts at Settlement; compare with the illustration given of similar quarters in Fryer (1910)

35. Guano railway and sheds at Settlement

13. PLANTS OF ASSUMPTION ISLAND

F. R. Fosberg and S. A. Renvoize

NOSTOC COMMUNE L.
Seen by Stoddart, 1967.

ACROSTICHUM AUREUM L.
S. l., Stoddart 1096 (K).

NEPHROLEPIS BISERRATA (Sw.) Schott
Near North Point, Stoddart 1097 (K).

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
S. l., Stoddart 1042 (K).

DACTYLOCTENIUM PILOSUM Stapf
S. l., Fox [=Dupont] 254 (K) (not seen); Stoddart 1072 (K).

ENTEROPOGON SECHELLENSIS (Bak.) Dur. & Schinz
S. l., Stoddart 1065 (K), 1109 (K), 1073 (K); Price in 1967 (BM); Dupont 238 (K), 257 (K); Settlement, Stoddart 1043 (K); West side, Frazier 17 (K).

ERAGROSTIS sp.
S. l., Dupont 109 (K), 237 (K), 252 (K).

ERIOCHLOA MEYERIANA (Nees) Pilg.
S. l., Stoddart 1063 (K); Dupont 75 (K).

ERIOCHLOA SUBULIFERA Stapf
S. l., Fox [Dupont] 258, 261 (K).

PANICUM ASSUMPTIONIS Stapf
S. l., Dupont 110 (K, type).

PENNISETUM POLYSTACHION (L.) Schult.
Southern part of West shore, Stoddart 1100 (K).

SCLERODACTYLON MACROSTACHYUM (Benth.) Camus
S. l., Gwynne & Wood 1335 (EA); Parts of east dunes, Stoddart 1088 (K).

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SPOROBOLUS VIRGINICUS L.
Along N. E. Coast, Stoddart 1093 (K).

STENOTAPHRUM CLAVIGERUM Stapf
East dune 3 mi. from north point, Stoddart 1090 (K).

FIMBRISTYLIS CYMOSA R. Br.
East dunes, Stoddart 1084 (K); West side, Frazier 21 (K, US).

COCOS NUCIFERA L.
Seen by Stoddart, 1967.

COMMELINA BENGHALENSIS L.
S. 1., Dupont 253 (K).

AGAVE SISALANA Perr.
Seen by Stoddart, 1967.

ASPARAGUS UMBELLULATUS Lieb.
Reported by Hemsley (1919) on authority of Dupont.

LOMATOPHYLLUM BORBONICUM Willd.
Settlement, Stoddart 1041 (K, US).

DIOSCOREA NESIOTIS Hemsl.
S. 1., Dupont 118 (K), 274 (K).

CASUARINA EQUISETIFOLIA L.
Seen by Stoddart, 1967.

FICUS NAUTARUM Bak.
S. 1., Stoddart 1078 (K); West side, Frazier 10 (K).

BOERHAVIA ELEGANS Choisy
S. 1., Stoddart 1081 (K); Settlement, Stoddart 1062 (K).

BOERHAVIA REPENS L.
S. 1., Gwynne & Wood 1330 (EA).

PISONIA GRANDIS R. Br.
Seen and photographed by Stoddart.

ACHYRANTHES ASPERA L.
S. 1., Stoddart 1048 (K); West side, Frazier 20 (K).

AMARANTHUS DUBIUS Mart. ex Thel.
East shore N. of Settlement, Stoddart 1106 (K); West side, Frazier 1 (K, US).

AMARANTHUS VIRIDIS L.
Settlement, Stoddart 1056bis (K).

LAGREZIA MADAGASCARIENSIS (Poir.) Moq.
S. 1., Dupont 248 (K); south of island, Dupont 113 (K).

PORTULACA cf. AUSTRALIS Endl.
S. 1., Dupont 216 (K), 114 (K); Stoddart 1092 (K); Thomasset 214 (K); West side, Frazier 3 (K). This is the plant commonly referred to *P. quadrifida*, which it does not resemble.

PORTULACA OLERACEA L.
S. 1., Stoddart 1083 (K); West side, Frazier 27 (K, US).

CISSAMPELOS PAREIRA var. HIRSUTA (Buch. ex DC.) Forman
Guano pits, Dupont 104 (K, 2 sheets), 104 (K); Dupont 263 (K).

CASSYTHA FILIFORMIS L.
S. 1., Stoddart 1074 (K).

CAPPARIS CARTILAGINEA Decne.
Seen and photographed by Stoddart, 1967.

CLEOME STRIGOSA (Boj.) Oliv.
Settlement, Stoddart 1059 (K); West side, Frazier 23 (K).

MAERUA TRIPHYLLA var. PUBESCENS (Kl.) De Wolf
S. 1., Stoddart 1085 (K); Dupont 270 (K), 260 (K); West side, Frazier 11 (K, US).

MORINGA OLEIFERA Lam.
Village, Stoddart 1107 (K).

CAESALPINIA BONDUC (L.) Roxb.
S. 1., Stoddart 1101 (K).

CANAVALIA ROSEA (Sw.) DC.
S. 1., Frazier 33 (K); Settlement, Stoddart 1046 (K); Dupont 29 (K); West side, Frazier 25 (K).

SOPHORA TOMENTOSA L.
S. 1., Stoddart 1104 (K); Dupont 262 (K).

TRIBULUS CISTOIDES L.
S. 1., Stoddart 1080 (K).

SURIANA MARITIMA L.
S. 1., Dupont 107 (K); Settlement, Stoddart 1057 (K).

ACALYPHA CLAOXYLOIDES Hutch.
West side, Frazier 29 (K, US).

ACALYPHA INDICA L.
West side, Frazier 30 (K).

EUPHORBIA ABBOTTII Baker
"Dupont records this from all the islands of the Seychelles region except Gloriosa..." Hemsley (1919). S. l., Fryer 52 (K); West side, Frazier 32 (K).

EUPHORBIA HIRTA L.
Settlement, Stoddart 1056 (K); West side, Frazier 31 (K).

EUPHORBIA INDICA Lam.
S. l., Stoddart 1089 (K); Dupont 292 (K).

EUPHORBIA PROSTRATA Ait.
West side, Frazier 2 (K, US).

PEDILANTHUS TITHYMALOIDES (L.) Poit.
Settlement, Stoddart 1038 (K).

PHYLLANTHUS AMARUS Sch. & Thonn.
West side, Frazier 4 (K, US).

ABUTILON FRUTICOSUM Guill.
S. l., Stoddart 1068 (K); West side, Frazier 26 (K, US).

GOSSYPIUM HIRSUTUM L.
Settlement, Stoddart 1058 (K); West side, Frazier 19 (K, US).

SIDA "DIFFUSA" HBK.
S. l., Dupont 111 (K).

SIDA PARVIFOLIA DC.
S. l., Stoddart 1094 (K); Dupont 264 (K).

THESPESIA POPULNEOIDES (Roxb.) Kostel.
S. l., Stoddart 1082 (K).

PASSIFLORA FOETIDA var. HISPIDA (DC.) Killip
S. l., Gwynne & Wood 1332 (EA); Stoddart 1076 (K).

PASSIFLORA SUBEROSA L.
S. l., Stoddart 1067 (K).

CARICA PAPAYA L.
Seen by Stoddart, 1967.

MOMORDICA CHARANTIA L.
S. l., Stoddart 1077 (K); Manager's garden, Stoddart 1108 (K).

PEMPHIS ACIDULA Forst.
S. l., Stoddart 1091 (K).

CERIOPS TAGAL (Perr.) C. B. Rob.
In deep hole inland, Stoddart 1098 (K).

TERMINALIA CATAPPA L.
Northern part of West shore, abandoned Settlement, Stoddart 1102 (K, US).

TERMINALIA BOIVINII Tul.
S. l., Dupont 272 (K).

AZIMA TETRACANTHA Lam.
West side, Frazier 12 (K); Settlement, Stoddart 1055 (K).

PLUMBAGO APHYLLA Boj. ex Boiss.
S. l., Vesey-FitzGerald 6008 (K); Gwynne & Wood 1334 (EA); Settlement, Stoddart 1052 (K); West side, Frazier 15 (K).

CATHARANTHUS ROSEUS (L.) G. Don
Settlement, Stoddart 1061 (K); West side, Frazier 9 (K).

PLEUROSTELMA CERNUUM (Decne) Bullock
S. l., Dupont 249 (K); West side, Frazier 16 (K).

SARCOSTEMMA VIMINALE R. Br.
S. l., Stoddart 1075 (K); West side, Frazier 14 (K).

SECAMONE FRYERI Hemsl.
S. l., Gwynne & Wood 1333 (EA); Stoddart 1066 (K); Dupont 115 (K).

Unidentified Asclepiadaceae
S. l., Frazier 34 (K).

EVOLVULUS ALSINOIDES L.
S. l., Gwynne & Wood 1331 (EA); West side, Frazier 28 (K).

IPOMOEA BATATAS (L.) Lam.
S. l., Stoddart 1079 (K), 1047 (K); West side, Frazier 8 (K).

IPOMOEA PES-CAPRAE (L.) R. Br.
Eastern windward beach crest, Stoddart 1087 (K); West side, Frazier 18 (K).

IPOMOEA TUBA (Schlecht) G. Don
S. l., Stoddart 1079 (K).

CORDIA SUBCORDATA Lam.
Northern part of west shore, Stoddart 1099 (K).

TOURNEFORTIA ARGENTEA L. f.
Settlement, Stoddart 1050 (K).

CLERODENDRUM GLABRUM E. Mey. (C. minutiflorum Baker).
S. l., Stoddart 1069 (K); West sandy shore, Stoddart 1103 (K); in guano pits, Dupont 105 (K).

NESOGENES DUPONTII Hemsl.
S. l., Dupont 250 (K), 106 (K, type?); Stoddart 1064 (K).

PREMNA OBTUSIFOLIA R. Br.
S. l., Dupont 247 (K).

STACHYTARPHETA JAMAICENSIS (L.) Vahl
S. l., Stoddart 1054 (K); West side, Frazier 5 (K).

DATURA METEL L.
Settlement, Stoddart 1045 (K); West side, Frazier 13 (K).

SOLANUM LYCOPERSICUM L.
Settlement, Stoddart 1044 (K).

SOLANUM NIGRUM L.
Settlement, Stoddart 1053 (K); West side, Frazier 22 (K).

LEONOTIS NEPETIFOLIA (L.) R. Br.
Settlement, Stoddart 1039 (K).

HYPOESTES ALDABRENSIS Bak.
S. l., Dupont 101 (K), 251 (K); Gwynne & Wood 1329; Settlement, Stoddart 1049 (K); West side, Frazier 6 (K).

HEDYOTIS sp.
S. l., Dupont 108 (K), 108bis (K); near South Point, Stoddart 1095 (US, K).

TARENNA TRICHANTHA (Bak.) Brem.
S. l., Dupont 116 (K).

TRIAINOLEPIS FRYERI (Hemsl.) Brem.
S. l., Dupont 259 (K).

SCAEVOLA TACCADA (Gaertn.) Roxb.
S. l., Stoddart 1051 (K).

LAUNAEA SARMENTOSA (Willd.) Alst.
S. l., Stoddart 1086 (K); Dupont 112 (K).

MELANTHERA BIFLORA (L.) H. Wild (*Wedelia biflora* (L.) DC.)
S. l., *Stoddart 1105* (K); Settlement, *Stoddart 1060* (K).

VERNONIA CINEREA (L.) Less.
S. l., *Stoddart 1040* (K); West side, *Frazier 24* (K, US, EA).

14. GEOGRAPHY AND ECOLOGY OF DESROCHES

D. R. Stoddart and M. E. D. Poore

Introduction

Desroches is a sand island on the windward rim of a slightly submerged atoll located 16 km east of the main Amirante Ridge. The atoll is 19-21 km in diameter; its rim has depths of 2-9 m on the north, east and south sides, and of 15-18 m on the west side. The lagoon is 18-31 m deep. There is a sounding of 1598 m between the atoll and the Amirante Ridge. Desroches island, which has been described by Baker (1963, 60-63), is elongate, 5.25 km long and 0.4-1.1 km wide, with an approximate area of 324 ha. Figure 7 is based on aerial photographs flown in 1960; there is no detailed land survey. Nothing is known of the condition of the peripheral reef of the atoll rim, and whether coral is active on it. Gardiner (1936, 435) drew attention to the absence of patch reefs and knolls within the lagoon.

The island is formed mainly of sand, and has a main elevation of 2-3 m. There is very little surface relief. The south coast especially is irregular, with deep bays surrounded by steep beaches of sand with cobbles (Plate 37 and 38). Beachrock outcrops patchily on the south coast (Plate 39). Beach erosion is taking place at the east and especially the western points; at the latter there is a small peninsula formed by layers of massive beachrock (Plate 40). No elevated reef-rock was seen. Piggott (1968) maps most of the island as Shioya Sand and Loamy Sand, with scattered patches of Jemo Series soils. The latter occur as rounded lumps of phosphate-cemented sand scattered over the surface.

Table 15 lists previous scientific work on Desroches. Coppinger (1883) contributed an important descriptive account following the visit of the *Alert*; Gardiner spent two days there during the Percy Sladen Expedition (Gardiner and Cooper 1907); but otherwise the most important systematic accounts are the recent ones by Baker (1963) and Piggott (1961, 43-47; 1968, 56).

Vegetation

By the time of Coppinger's visit in 1882, the vegetation was dominated by "several large groves of tall *Casuarina* trees, many...one hundred and eleven feet [34 m] in height". Coconuts had been planted

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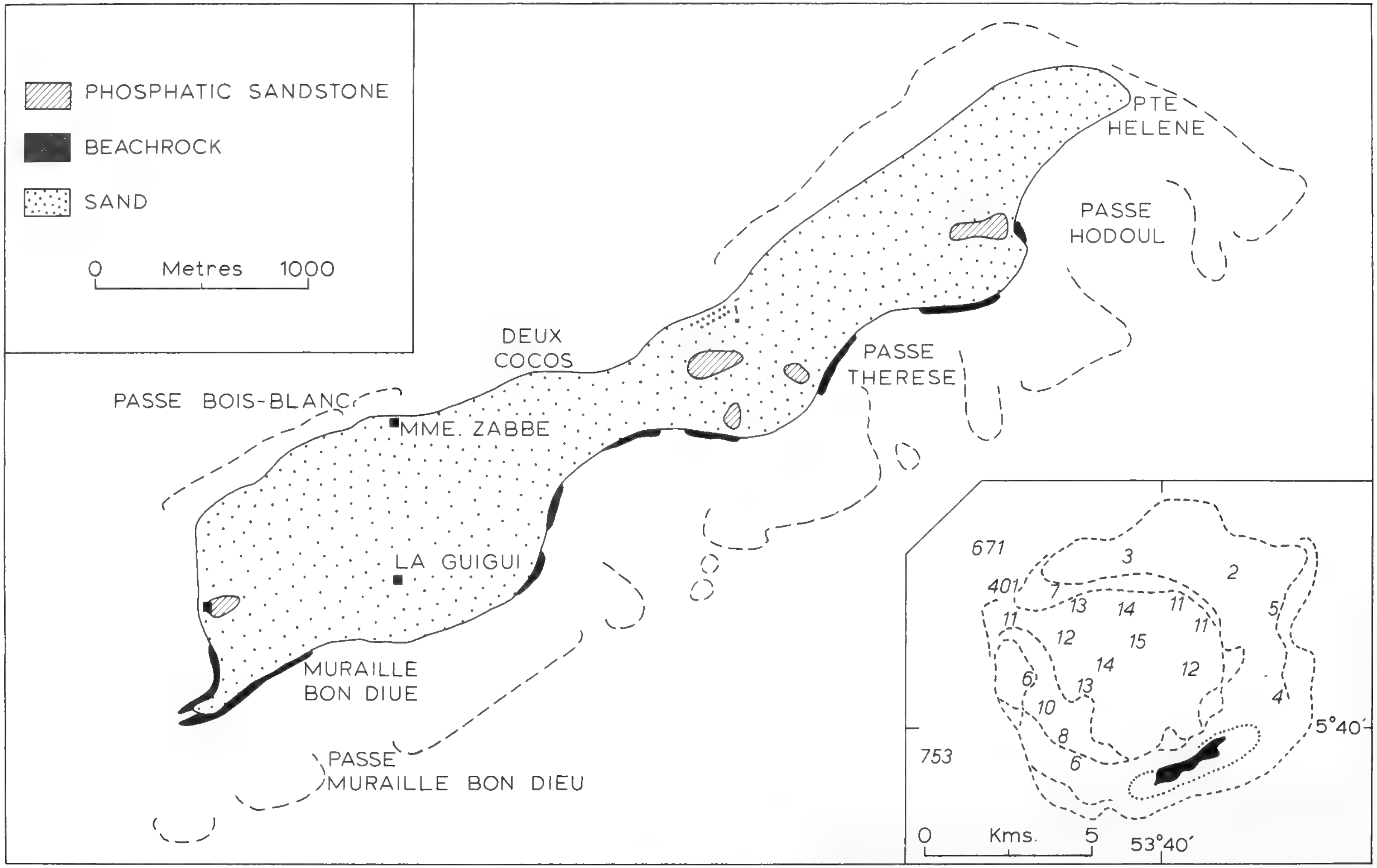

Fig. 7. Desroches

Table 15. Scientific studies at Desroches

Date	Study	Reference
1770	M. du Roslan: first recorded visit	Findlay (1882)
c. 1837	H. Dufo: mollusca	Dufo (1840)
1882 March 25-29	H.M.S. Alert, Dr R. Coppinger: Collections of birds and marine fauna. Hydrographic survey by Capt. J. P. Maclear	Coppinger (1883); Coppinger et al. (1884); Admiralty Chart 724
1892 Aug. 26	W. L. Abbott: birds	Ridgway (1895)
1905 Oct. 14-15	H.M.S. Sealark: J. S. Gardiner and Percy Sladen Expedition party	Gardiner and Cooper (1907), Gardiner (1936)
1960 Nov. 2-4	B. H. Baker, C. J. Piggott: geology, soils	Piggott (1961, 43-47; 1968, 56) Baker (1963)
1965 March 5	W.H.T. Tams and I.W.B. Nye: insects	
1967 Sept. 24	M. D. Gwynne, D. Wood, I. S. C. Parker: plants, birds	Parker (1970); Gwynne and Wood (1969)
1968 Sept. 21	M. E. D. Poore, D. R. Stoddart General observations; collection of plants	This report; Fosberg and Renvoize (1970)

extensively, though few were old enough to bear, and at the time of this visit vanilla was being planted round the bases of the Casuarina trees. Coppinger noted that the flora was "more extensive than that of the other islands"; he recorded Scaevola taccada, a Ficus (possibly introduced), the only fern he saw in the Amirantes (Nephrolepis), and "herbaceous plants of the families Malvaceae, Solanaceae, Cinchonaceae, and Convolvulaceae" (Coppinger 1883, 223).

Gardiner and Cooper (1907, 155) state that the Casuarina was planted about 1835, and though the island was abandoned the tree rapidly spread over it. A new settlement was established about 1880, when coconuts were planted. At the time of the Percy Sladen visit in 1905 the Casuarina was being cut and coconuts were being encouraged. At that time there was an enormous clump of Casuarina at the west end, more along the south side to the village, and clumps at the east end. Gardiner commented on the lack of ground vegetation beneath these trees.

Thus the vegetation of Desroches, which has been continuously managed since 1905, has a long history of human interference. It is now actively managed as a copra island, with labourers clearing undergrowth and preventing the establishment of shrubs, as well as planting coconuts. With the exception of littoral Scaevola, Piggott (1961, 45) found "no evidence of the original vegetation. In other ways the flora is very

poor; the number of species is extremely limited and is diminishing under the existing system of nearly clean cultivation". This is somewhat exaggerated, for though vegetation growth is controlled there is a fairly complete ground cover, and our collections in 1968 totalled some 60 species (Fosberg and Renvoize 1970). There are no rainfall records for Desroches, but data for Darros and Alphonse in the Amirantes suggest an annual total of about 1500 mm, substantially more than occurs on the islands immediately north of Madagascar.

Undisturbed vegetation is now limited to nearshore areas. On the south coast Scaevola taccada is dominant, forming a tall hedge, with occasional Suriana maritima and Tournefortia argentea (Plates 37 and 38). Guettarda speciosa is commonly found fringing the Scaevola hedge on its landward side. On the north coast Scaevola is again dominant (Plate 41), forming taller and more open shrubs, with scattered tall trees of Ochrosia oppositifolia, Guettarda speciosa, Pipturus argenteus and Cordia subcordata. These species are presumably indicative of the original tree flora of the island. Elsewhere the vegetation is completely dominated by tall Casuarina equisetifolia and planted coconuts (Plate 42). A few other trees are occasionally found in the centre of the island, especially at the southwest end (Guettarda speciosa, Morinda citrifolia, large Ficus, Terminalia catappa), but otherwise the only trees on the island are huge specimens of Hernandia sonora forming an avenue at the settlement. Gardiner and Cooper (1907, 155) recorded these, together with Barringtonia asiatica. We did not see the latter, but did record Calophyllum inophyllum, also at the settlement. Decorative trees such as Delonix regia and Tamarindus indicus and economic trees such as Carica papaya are found at the main settlement and at smaller settlements around the island. A single bryophyte, Calymperes sanctae-mariae Besch. (det. C. C. Townsend), was taken on a rotten Casuarina trunk; this species has also been collected at Aldabra and Diego Garcia.

A shrub or tall herb layer is almost absent under the coconuts, apart from some Gossypium hirsutum and tall Alocasia near the main settlement. The tallest plants of the ground layer are Kalanchoe pinnata, Stachytarpheta jamaicensis and Turnera ulmifolia, but especially near the settlement the vegetation is kept closely cropped and these plants are not important. Grasses collected include species of Eragrostis, Stenotaphrum micranthum, Cynodon dactylon, Dactyloctenium aegyptium, Eleusine indica, and taller Digitaria horizontalis and Enteropogon sechellensis; the sedges Cyperus dubius, Cyperus ligularis and Fimbristylis cymosa are all common. The fern Nephrolepis biserrata is widespread, especially towards the northeast end of the island. The remaining species of the ground layer form a diverse assemblage of flowering plants, comprising:

Bidens pilosa	Phyllanthus amarus
Euphorbia hirta	Phyllanthus maderaspatensis
Euphorbia prostrata	Sida parvifolia
Gynandropsis gynandra	Striga asiatica
Lippia nodiflora	Tridax procumbens
Passiflora suberosa	Vernonia cinerea

Cassytha filiformis is very widespread, especially on open ground between the seaward *Scaevola* hedge and the coconut woodland. *Ipomoea* is very uncommon: *I. pes-caprae* was only found in one place on the lagoon beach crest. A single specimen of *Euphorbia cyathophora* was found at the settlement cemetery.

The settlement itself (Plates 43 and 44) has the usual assemblage of decorative and economic plants, apart from the trees already mentioned. The decoratives include species of *Gaillardia*, *Catharanthus roseus*, *Tagetes patula*, *Pedilanthus tithymaloides* and *Mirabilis jalapa*; the economic plants *Moringa oleifera*, *Ricinus communis*, *Agave*, *Musa*, and maize. *Caesalpinia* sp. is also present.

The combination of *Casuarina* and *Cocos* forms a most attractive woodland, and Piggott (1961, 44) noted that "palm yields tend to be much higher when next to a large *Casuarina* and their leaves are rich dark green". Nevertheless he later (1968, 56) stated that *Casuarina* "is notorious for the way it reduces fertility. Nothing grows underneath. Some still remain and, other than those necessary as windbreaks, should be cut down as soon as possible". We feel that more consideration should be given to this question before the trees are cut.

Fauna other than Birds

Apart from the birds very little indeed is known of the fauna of Desroches. Small collections of marine fauna were made by the *Alert* expedition: they include 8 species of marine Mollusca (Smith 1884), one echinoderm (Bell 1884), and either 4 or 8 species (locations are doubtful) of Crustacea (Miers 1884). The Percy Sladen party apparently completely neglected the marine fauna and flora during their visit.

Of the terrestrial fauna, a single reptile *Hemidactylus brookii* was recorded by Boulenger (1909), two spiders by Hirst (1911), and three species of terrestrial isopods by Budde-Lund (1912). About forty species of insects were collected by the Percy Sladen party, and the references to the determinations are given in Table 16.

Birds

Land birds

The following are recorded from Desroches:

Streptopelia sp.

According to Coppinger: "I saw only once. But one of the Creoles living on the island told me that it was an indigenous species, and was quite distinct from the domestic pigeons which roost about and restrict their range to the houses and trees about the settlement" (1884, 225). There is no later record of either; Benson (1970) discusses *Streptopelia* in the Amirantes.

Table 16. Insects recorded from Desroches by the Percy Sladen Expedition

Group	Number of species	Reference
Orthoptera	10	Bolivar (1912, 1924)
Dermaptera	1	Burr (1910)
Hemiptera	4	Green (1907), Distant (1909)
Lepidoptera	9	Fletcher (1910)
Coleoptera	7	Champion (1914), Scott (1912, 1926), Arrow (1922)
Hymenoptera	6	Cameron (1907), Forel (1907, 1912), Meade-Waldo (1912)
Diptera	1	Theobald (1912)

Passer domesticus

Reported (as *P. indicus*) by Abbott in Ridgway (1895), and included by Watson et al. (1963). Common at the Settlement in 1968.

Foudia madagascariensis

Collected by Abbott on 26 August 1892 (Ridgway 1895), and "with great difficulty" by Coppinger (1884, 224) "in the large *Casuarina* grove, near the western end of the island"; "the females were nesting". Fairly common at the settlement in 1968 but only infrequently seen elsewhere. Status unknown according to Watson et al. (1963).

Francolinus pondicerianus

Coppinger (1884, 224) noted a "red-legged partridge", Abbott in Ridgway (1895) a partridge, and Gardiner and Cooper (1907, 156) a wild partridge. Seen in 1968 on the seaward side near the cemetery.

Estrilda astrild

Coppinger (1884, 224) noted "a very small bird which was to be seen every now and then flitting in large flocks among the maize plants and low bushes". He thought it a waxbill and it may have been this species. There is no later record.

Serinus mozambicus

Collected by Coppinger, recorded as *Crithagra chrysopyga* in Sharpe (1884). Coppinger states: "The yellow-breasted finch is gregarious, and mostly frequents the tops of the cocoa-nut trees and the upper branches of the tall Casuarinas" (1884, 224). One specimen collected on 26 August 1892 by Abbott (Ridgway 1895, as *Serinus icterus*). Introduced, according to Gardiner and Cooper (1907, 106).

In addition to these records, Coppinger also noted a brown finch "not abundant", which "seemed to confine its range to the plantations of young coconuts, where it was continually shifting its perch" (1884, 224).

Shore birds

Bubulcus ibis
Recorded as *Bubulcus bubulcus* by Abbott in Ridgway (1895) and in Watson et al. (1963). Not seen in 1968.

Butorides striatus
Recorded as *Butorides atricapilla* by Abbott in Ridgway (1895) and in Watson et al. (1963). Seen inland in 1968.

Migrants

Numenius phaeopus
Recorded by Abbott in Ridgway (1895). Quite common and vocal in woodland in 1968.

Actitis hypoleucos
Sight record, September 1968.

Arenaria interpres
Listed generally by Parker (1970) after his visit in 1967.

Sea birds

Puffinus pacificus
Seen at sea between Desroches and Mahé by Parker (1970).

Puffinus l'herminieri
Seen at sea between Desroches and Mahé by Parker (1970).

Sterna fuscata
Seen by Parker in September 1967 and by Poore and Stoddart in September 1968.

Anous stolidus
Seen by Parker in September 1967 and by Poore and Stoddart in September 1968.

Gygis alba
"Very common" according to Parker in 1967, but not seen by Poore and Stoddart in September 1968.

Other species of shore birds, migrants and sea birds are likely to occur on Desroches in view of the list for the Amirantes in Watson et al. (1963, 179-182).

History and Settlement

Desroches was discovered by Europeans later than most of the islands immediately north of Madagascar. The island is said to be identical with the "Ile du Berger" discovered by Du Roslan in 1770, when "good water" was found. But Du Roslan described the Ile du Berger as consisting of two separate islands with a channel passable at low water between them (Findlay 1882, 128). Such a description would fit Poivre rather than Desroches, but Du Roslan's navigation then becomes difficult to follow. Ile du Berger was named after his ship Heure du Berger, and Desroches after the Chevalier Desroches, Governor General of the Ile de France and Bourbon.

Casuarina trees were planted during a brief settlement in 1835. A new settlement was established in 1875-1880, and coconut planting was begun. Since that time the island has been continuously inhabited, and Casuarinas have been cut and coconuts planted at intervals. The manager's house, offices and plantation works were laid out between 1910 and 1920 (Plates 43 and 44). By 1882 there were already pigs and poultry on the island, and fruit and vegetables were grown (Coppinger 1884, 223). Cats and rabbits were noted in 1905 (Gardiner and Cooper 1907, 156), but there is no further reference to rabbits and the reference may be mistaken. There are now pigs and poultry on Desroches, together with about seventy semi-feral donkeys formerly used in the coconut mills. The manager has a lorry and there is a network of motorable roads. In 1967 copra production was 179 tons.

Desroches has clearly changed so much in the last hundred years that little evidence of its original biota remains. The vegetation is dominated by a man-induced woodland, with a characteristic assemblage of wide-ranging species beneath the coconuts and Casuarina. There are no certain references to breeding land birds, and the only common species in 1968 (the house sparrow and the Madagascar Fody) are both introduced. The extent of human disturbance may likewise account for the paucity of records of shore birds and sea birds: it is unlikely that any of the species noted now nests on Desroches. No collections of the terrestrial invertebrates have been made since Gardiner's in 1905, but it is probable, that like the plants, many of the species now there represent deliberate or accidental introductions.

Desroches was administered as a dependency of Seychelles between 1903 and 1965, when it was incorporated in the British Indian Ocean Territory.

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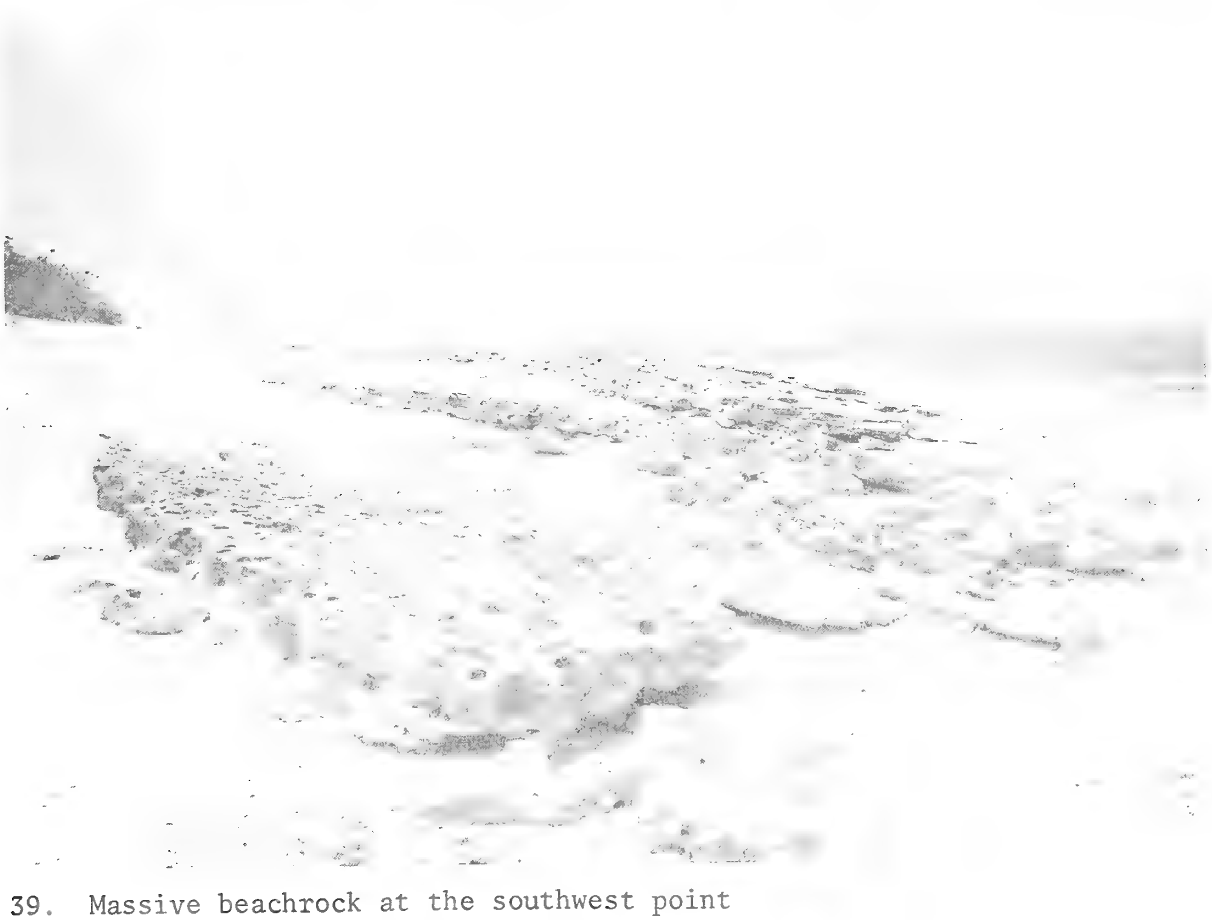
36. Scaevola and Casuarina on the south coast near Pointe Helene

37. Suriana on the south coast near Muraille Bon Dieu

38. Massive beachrock near the centre of the south coast



39. Massive beachrock at the southwest point

40. Scaevola and Cocos on the lagoon shore at Settlement

41. Mixed Cocos and Casuarina woodland near La Guigui

42. Labourers' quarters at Settlement, the path flanked by Cocos and Hymenocallis

43. Labourer's quarters at Settlement

15. PLANTS OF DESROCHES ISLAND

F. R. Fosberg and S. A. Renvoize

CALYMPERES SANCTAE-MARIAE Besch.
Stoddart & Poore s. n. (Det. C. C. Townsend).

NEPHROLEPIS BISERRATA (Sw.) Schott
Stoddart & Poore 1419 (K, US).

CYMODOCEA CILIATA Ehrenb. ex Aschers.
Gwynne & Wood 1031a (K, EA).

CYNODON DACTYLON (L.) Pers.
Stoddart & Poore 1390 (K, US)

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
Gwynne & Wood 1039 (EA) (small plant with 1-2 spikes about 1 cm long, possibly not this species); Stoddart & Poore 1413 (K).

DIGITARIA HORIZONTALIS Willd.
Gwynne & Wood 1034 (K, EA); Stoddart & Poore 1414 (K, US).

ELEUSINE INDICA (L.) Gaertn.
Gwynne & Wood 1045 (EA); Stoddart & Poore 1405 (K).

ENTEROPOGON SECHELLENSIS (Baker) Dur. & Schinz
Stoddart & Poore 1417 (K, US); Gwynne & Wood 1044 (EA).

ERAGROSTIS TENELLA (L.) Beauv.
Gwynne & Wood 1033 (EA); Stoddart & Poore 1404 (K), 1423 (K, US).

ERAGROSTIS sp.
Stoddart & Poore 1393 (K); Gwynne & Wood 1043 (EA).

STENOTAPHRUM MICRANTHUM (Desv.) Hubb.
Stoddart & Poore 1391 (K, US).

ZEA MAYS L.
Seen by Stoddart (1968).

CYPERUS DUBIUS Rottb.
Gwynne & Wood 1048 (EA), 1036 (EA); Stoddart & Poore 1428 (K).

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CYPERUS LIGULARIS L.
Stoddart & Poore 1412 (K, US).

FIMBRISTYLIS CYMOSA R. Br.
Gwynne & Wood 1032 (EA); Stoddart & Poore 1410 (K).

COCOS NUCIFERA L.
Seen by Stoddart (1968).

ALOCASIA?
Seen by Stoddart (1968).

AGAVE SISALANA Perr.?
Seen by Stoddart (1968).

MUSA SAPIENTUM L.
Seen by Stoddart (1968).

CASUARINA EQUISETIFOLIA L.
Seen by Stoddart (1968).

FICUS sp.
Seen by Stoddart (1968).

PIPTURUS ARGENTEUS Gaud. ex Wedd.
Stoddart & Poore 1399 (K, P, EA, US).

MIRABILIS JALAPA L.
Stoddart & Poore 1398 (K).

CASSYTHA FILIFORMIS L.
Stoddart & Poore 1418 (K).

HERNANDIA SONORA L.
Gwynne & Wood 1041 (EA); Stoddart & Poore 1388 (K, US).

GYNANDROPSIS GYNANDRA (L.) Briq.
Stoddart & Poore 1400 (K).

MORINGA OLEIFERA Lam.
Seen by Stoddart (1968).

KALANCHOE PINNATA (Lam.) Pers.
Stoddart & Poore 1408 (K, US).

CAESALPINIA sp.
Seen by Stoddart (1968).

DELONIX REGIA (Boj.) Raf.
Seen by Stoddart (1968).

TAMARINDUS INDICA L.
Stoddart & Poore 1402 (K).

SURIANA MARITIMA L.
Gwynne & Wood 1037 (K, EA); Stoddart & Poore 1420 (K, US).

EUPHORBIA CYATHOPHORA Murr.
Stoddart & Poore 1389 (K).

EUPHORBIA HIRTA L.
Stoddart & Poore 1396 (K, US).

EUPHORBIA PROSTRATA Ait.
Gwynne & Wood 1046 (EA) (no fruit); Stoddart & Poore 1415 (K, US).

PEDILANTHUS TITHYMALOIDES (L.) Poit.
Seen by Stoddart (1968).

PHYLLANTHUS AMARUS Schum. & Thonn.
Stoddart & Poore 1406 (K).

PHYLLANTHUS MADERASPATENSIS L.
Gwynne & Wood 1050 (EA), 1040 (EA); Stoddart & Poore 1416 (K, US).

RICINUS COMMUNIS L.
Seen by Stoddart (1968).

GOSSYPIUM HIRSUTUM L.
Seen by Stoddart (1968).

SIDA PARVIFOLIA DC.
Gwynne & Wood 1035 (EA); Stoddart & Poore 1422 (K).

CALOPHYLLUM INOPHYLLUM L.
Coppinger in 1822, label mounted "specimen not laid in" (K). Seen by Stoddart (1968).

TURNERA ULMIFOLIA L.
Stoddart & Poore 1425 (K, US).

PASSIFLORA SUBEROSA L.
Stoddart & Poore 1403 (K, US).

CARICA PAPAYA L.
Seen by Stoddart (1968).

BARRINGTONIA ASIATICA (L.) Kurz
Reported by Gardiner & Cooper (1907), not seen during present survey.

TERMINALIA CATAPPA L.
Seen by Stoddart (1968).

CATHARANTHUS ROSEUS (L.) G. Don
Stoddart & Poore 1395 (K).

OCHROSIA OPPOSITIFOLIA (Lam.) K. Schum.
Stoddart & Poore 1401 (K, US).

IPOMOEA PES-CAPRAE (L.) R. Br.
Stoddart & Poore 1329 (K, US).

CORDIA SUBCORDATA Lam.
Seen by Stoddart (1968).

TOURNEFORTIA ARGENTEA L. f.
Seen by Stoddart (1968).

LIPPIA NODIFLORA L.
Stoddart & Poore 1427 (K).

STACHYTARPHETA JAMAICENSIS (L.) Vahl
Stoddart & Poore 1424 (K).

STRIGA ASIATICA (L.) O. Ktze.
Stoddart & Poore 1409 (K).

GUETTARDA SPECIOSA L.
Gwynne & Wood 1038 (K, EA); Stoddart & Poore 1421 (K).

MORINDA CITRIFOLIA L.
Stoddart & Poore 1407 (K, US).

SCAEVOLA TACCADA (Gaertn.) Roxb.
Seen by Stoddart (1968).

BIDENS PILOSA L.
Stoddart & Poore 1394 (K, US).

GAILLARDIA LANCEOLATA Michx?
Seen by Stoddart (1968).

TAGETES PATULA L.
Stoddart & Poore 1397 (K).

TRIDAX PROCUMBENS L.
Stoddart & Poore 1426 (K).

VERNONIA CINEREA (L.) Less.
Coppinger, label mounted "specimen not laid in" (K); Gwynne & Wood 1047 (EA); Stoddart & Poore 1411 (K).

16. GEOGRAPHY AND ECOLOGY OF REMIRE

D. R. Stoddart and M. E. D. Poore

Introduction

Remire or Eagle Island is a small oval-shaped island, 0.8 km in diameter and with an area of 80 hectares. It stands at the south end of a long north-south trending reef, but is detached from it. Remire itself stands on a small reef flat which extends from the shore for 140-370 m on the northwest and southeast sides (Figure 8). Surrounding water depths are generally less than 35 m (Baker 1963, 51-54).

The island is mainly sandy, with littoral beachrock on the south and east shores. Much of the interior, however, has been converted into a phosphatic rock, with horizontal pitted and irregular surface, covered with loose cobble-size fragments. This plate of phosphate rock, at least 1.5 m thick, outcrops at the southeast corner to form a steep cliff 3-4 m high on the shore. The phosphate surface is rather higher than that of unconsolidated sand, but it has been much modified by mining. Braithwaite (1968) has discussed the formation of the phosphate rock. Piggott (1968, 60-61) distinguishes the soil of the phosphate areas as Jemo Series.

As in the case of Desroches, Remire was briefly visited by the *Alert* and Percy Sladen Expeditions in 1882 and 1905. Table 17 lists other scientific visitors. The following account is based on a short visit on 26 September 1968.

Vegetation

The vegetation of Remire has changed considerably since it was first discovered. Horsburgh (1852, 182) referred to it as "covered with shrubs" and Coppinger (1883, 220) as "covered with a thick growth of stunted bushes". Gardiner and Cooper (1907, 157) stated that "there are as yet no high trees and the shrubs are as small and stunted as at Cargados. A few coconuts have been planted to the north in the last ten years. But it is only recently that the last of the guano has been removed and the island let for cultivation. A clump of screw-pines (*Pandanus Balfouri*) in the centre of the island was an unusual feature".

The island is now covered with a dense coconut-dominated woodland on the sand areas, and a more open vegetation, with trees but without

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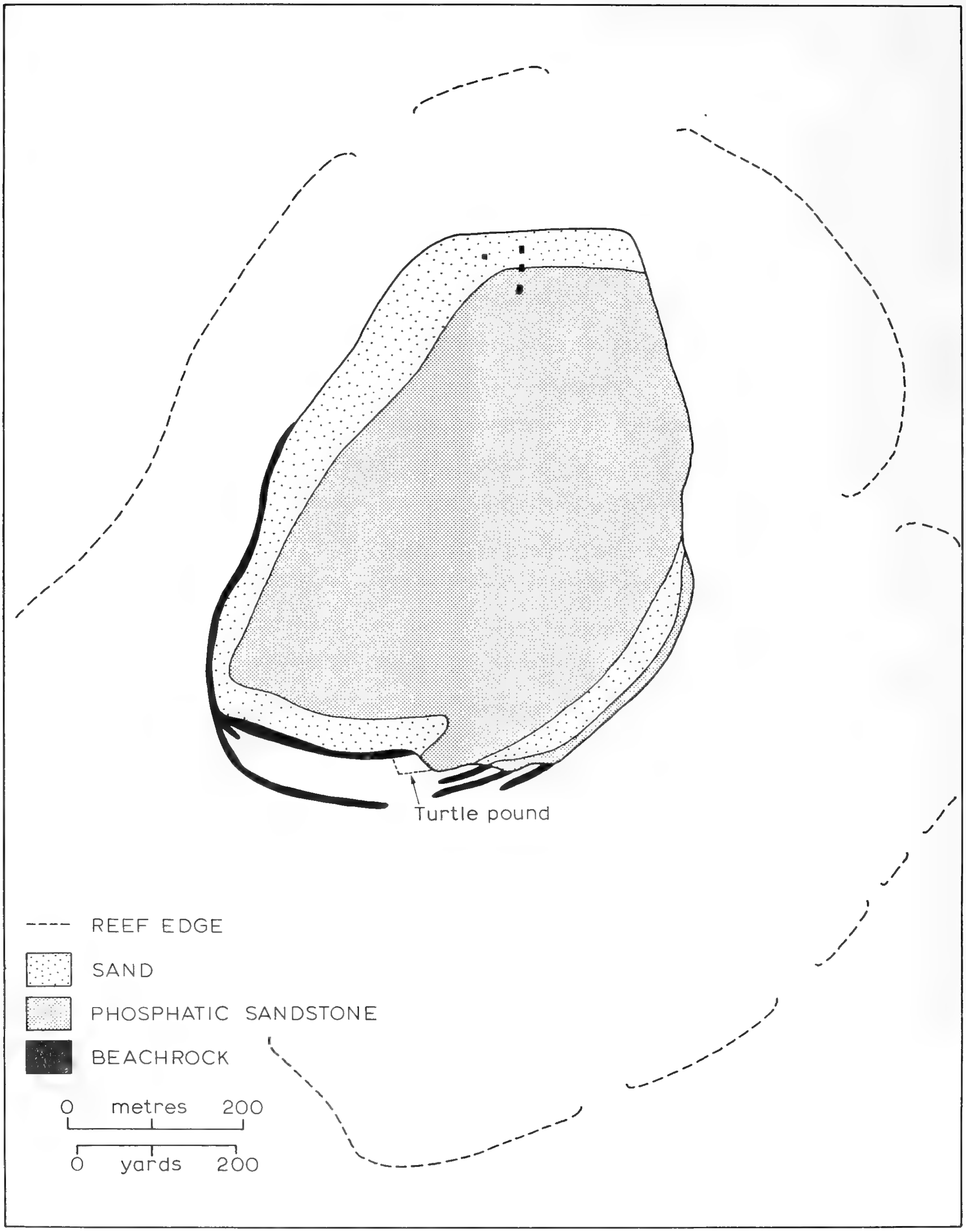

Fig. 8. Remire (after Baker 1963, Fig. 10)

Table 17. Scientific studies at Remire

Date	Study	Reference
1770	Explored by Du Roslan	
1771	Explored by M. de la Biollière, in the Eagle	Horsburgh (1852)
1882 March 19-20	H.M.S. Alert, R. W. Coppinger: general observations, bird collecting; Hydrographic survey by Capt. J. P. Maclear	Coppinger (1883), Coppinger et al. (1884), Admiralty Chart 724
1901	Visit by G. Naylor for Baty, Bergne and Co.	Bergne (1900)
1905 Oct. 17	Percy Sladen Expedition, H.M.S. Sealark: J. S. Gardiner, land collections, mainly insects	Gardiner and Cooper (1907), Gardiner (1936)
1955 July 5, Aug. 16	Viscount Ridley, Lord Richard Percy: birds	Ridley and Percy (1958)
1960 Nov. 2	B. H. Baker, C. J. Piggott: geology, soils	Baker (1963), Piggott (1961, 66-67; 1968, 60-61)
1965	C. J. R. Braithwaite, B. R. Rosen: geology of phosphate deposits, modern corals	Braithwaite (1968)
1967 Sept. 21-22	M. D. Gwynne, D. Wood, I. S. C. Parker: plants, birds	Parker (1970), Gwynne and Wood (1969)
1968 Sept. 26	M. E. D. Poore, D. R. Stoddart: plants, general observations	This report; Fosberg and Renvoize (1970)

coconuts, on the phosphate areas. A third vegetation type consists of a littoral hedge surrounding the island, dominated by Scaevola taccada, with Suriana maritima and Tournefortia argentea, with trees on its inner edge of Cordia subcordata and Guettarda speciosa.

The coconut woodland includes much Casuarina equisetifolia, and occasional Ficus nautarum, Thespesia populneoides, Terminalia catappa and other trees. The settlement area on the west coast is surrounded by a row, clearly planted, of tall Ochrosia oppositifolia, and at the settlement there are tall trees of Hernandia sonora and Calophyllum inophyllum. The ground layer in the coconut woodland consists of the following common species: together with grasses (Cenchrus echinatus, Stenotaphrum micranthum) and sedges (Cyperus dubius),

Acalypha indica	Euphorbia hirta
Achyranthes aspera	Lippia nodiflora
Boerhavia repens	Phyllanthus maderaspatensis
Bidens pilosa	Sida parvifolia
Cassia occidentalis	Solanum nigrum
Cassytha filiformis	Stachytarpheta jamaicensis
Cleome viscosa	Turnera ulmifolia

The vegetation of the phosphate area is highly variable. Two tree-dominated communities can be distinguished: one with a dense growth of Leucaena leucocephala about 5 m tall, the other a more open community of Carica papaya with a ground cover on a very irregular surface of Ipomoea pes-caprae and subsidiary Boerhavia repens, Bidens pilosa and Stenotaphrum micranthum. On the east side of the island, trees on the phosphate are rare, and much of the irregular surface is again covered with a thick mat of Ipomoea pes-caprae. Where the surface is smooth, probably because of superficial quarrying, the dominance of Ipomoea is reduced and other species, such as Tridax procumbens and Cyperus ligularis, appear. Weeds on this treeless phosphate are common along paths, where they include Eragrostis sp., Dactyloctenium aegyptium, Stachytarpheta jamaicensis, Cassytha filiformis and Portulaca oleracea.

The settlement has a number of decoratives (Catharanthus roseus, Datura metel) and other cultivated plants (Moringa oleifera, Capsicum frutescens, Agave, Carica papaya, a large cucurbit).

The contrast between the present wooded island and that described before 1905 is striking. Remire is at present uninhabited, no clearing of ground vegetation takes place, and the growth in many places is very dense.

Fauna other than Birds

The Alert expedition made small collections, mostly of marine fauna, including 9 species of marine molluscs (Smith 1884), one sponge (Ridley 1884), and either 1 or 6 (location uncertain) crabs (Miers 1884). Coppinger (1883) recorded a Coenobita as being particularly common. The Percy Sladen Expedition made almost no collections of marine fauna and flora in 1905. Both the Alert and the Percy Sladen collected a single gecko Hemidactylus frenatus (Gunther 1884, Boulenger 1909). Ridley and Percy (1958, 43) record in addition Mabuia sechellensis. No lizards were seen in 1968. Some 35 species of insects were recorded by the Percy Sladen team, in addition to three beetles collected by Coppinger (Waterhouse 1884): the references to the Percy Sladen insects are tabulated in Table 18.

Birds

The bird fauna of Remire shows interesting contrasts with that of the neighbouring larger island of Desroches. Neither has any native land birds, though more have been introduced to the larger island. Few migrants have been recorded on either island, though this largely reflects lack of observation. Remire has a much more diverse sea bird fauna, dominated by terns, especially Sterna fuscata, Gygis alba and Anous tenuirostris. The island was probably a more important sea bird breeding ground in the past, before mining began, and sea bird populations

Table 18. Insects recorded from Remire by the Percy Sladen Expedition

Group	Number of species	Reference
Orthoptera	5	Bolivar (1912, 1924)
Dermaptera	1	Burr (1910)
Hemiptera	2	Green (1907), Distant (1909)
Lepidoptera	8	Fletcher (1910)
Coleoptera	15	Aurivillius (1922), Champion (1914), Gebien (1922), Schenkling (1922), Scott (1912, 1917, 1926), Fleutiaux (1923)
Hymenoptera	3	Cameron (1907), Forel (1907), Meade-Waldo (1912)
Diptera	3	Lamb (1912, 1914, 1922)

may have affected the vegetation and restricted it to shrubs. Ridley and Percy (1958) considered the Sooty Tern population to be in danger of extinction, and pointed out that the export of eggs had declined from 300 cases (210 000 eggs) in 1931 to 105 cases (73 500 eggs) in 1954. At the time of our visit there were no more than a few hundred terns, mainly in tall *Casuarina* on the southwest coast. The absence of boobies is striking.

Land birds

There are no native land birds on Remire. Four species of introduced land birds have been recorded from time to time:

Francolinus pondicerianus

Coppinger (1883, 220) found "a small red-legged partridge, which was very abundant, and afforded us some good shooting"; a specimen was collected (Bowdler-Sharpe 1884). Not recorded since.

Gallus gallus

Coppinger (1883, 220) noted domestic fowl gone wild, with chickens which "on being disturbed, rose and took to flight like pheasants". Not recorded since.

Cisticola cherina

A small active warbler, possibly this species, was seen in coastal *Scaevola* by Poore and Stoddart in 1968. It had the same metallic tic-tic-tic call as the Astove and Cosmoledo *Cisticola*. Not previously recorded.

Foudia madagascariensis
First recorded, ♂ collected, by Parker, 22 September 1967.

Shore birds

Ardea cinerea
Three seen by Parker, 22 September 1967.

Migrants

Squatarola squatarola
Seen by Parker, 22 September 1967.

Charadrius leschenaultii
♀ collected by Parker, 22 September 1967.

Numenius phaeopus
Seen and recorded as common by Parker in 1967, seen by Poore and Stoddart in September 1968.

Arenaria interpres
Seen by Parker 22 September 1967.

Crocethia alba
Seen by Parker 22 September 1967.

Sea birds

Puffinus sp.
Coppinger (1883) recorded a "night petrel in burrows". There is no other record.

Phaethon lepturus
Four seen by Parker, 1967.

Fregata minor
"Frigate birds" common, roosting in coconuts (Ridley and Percy 1958, 18). Seen by Parker, 1967, and by Poore and Stoddart (probably this species) in September 1968.

Fregata ariel
Seen by Parker, September 1967.

Sterna anaethetus
♂ ♀♀♀ collected by Parker, 22 September 1967.

Sterna fuscata
Reported by Vesey-FitzGerald (1941) to breed, but population reduced and spasmodic. Ridley and Percy (1958) found 3200 pairs in two separate colonies and considered that the population could be in

danger of extinction because of excessive egg-collecting. ♂ collected by Parker, 22 September 1967. A few hundred seen by Poore and Stoddart, September 1968.

Thalasseus bergii

♂♂♂♀ collected by Parker, 22 September 1967, who saw about 200. seen also by Poore and Stoddart in September 1968.

Anous stolidus

♂ ♀♀ collected by Parker, 22 September 1967, and seen by Poore and Stoddart in September 1968.

Anous tenuirostris

8 ♀♀ collected by Parker on 22 September 1967. Parker reported it to be by far the most common bird on Remire, though he did not see it on the other islands he visited (these did not include African Banks). Seen also by Poore and Stoddart in September 1968.

Gygis alba

Found nesting by Vesey-FitzGerald (1941). Noted as "very common" by Parker, who collected ♂ ♀♀ on 22 September 1967. Seen by Poore and Stoddart in September 1968.

More species of shore birds, migrants and sea birds will probably be recorded, in view of the list for the Amirantes in Watson et al. (1963, 179-182).

History and Settlement

Remire was still apparently uninhabited in 1882, though discovered in 1770. Coppinger (1883), however, reports finding the ruins of a solidly built stone house in the centre of the island. Guano-mining was carried on for some years after Coppinger's visit, and was extensive in 1900 when visited by H. A'C. Bergne. Huts and a shed were built during this period (Bergne 1900). Mining was reported to be complete by 1905, according to Gardiner and Cooper (1907). The island has been visited regularly during this century for birds' eggs, but it is not known how continuous human settlement has been. In 1898 about one third of the island had been planted with about 1750 coconuts, which were doing well, together with maize and pumpkins (Bergne 1900). Messrs Baty, Bergne and Co. held the lease of Remire until 1926. In 1901 there were guano sheds and a tramway for the export of guano, and other installations included an iron house, a boat house, a store and other sheds. Of these there is now no trace. In the last few years, while the lease was held for a period by R. M. Veevers-Carter, several new buildings were erected, including a large house in Moorish style, reservoir, copra drier, and turtle pen; but when Mr Veevers-Carter moved to Astove the Seychelles Development Corporation employed only a caretaker on Remire, which was uninhabited in September 1968.

Rats have been introduced, but apart from the birds we saw no other exotic animals in 1968.

Remire has been administered as a dependency of Seychelles since 1903, and was not included in the British Indian Ocean Territory in 1965.

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17. PLANTS OF REMIRE (EAGLE) ISLAND, AMIRANTES

F. R. Fosberg and S. A. Renvoize

NEPHROLEPIS BISERRATA (Sw.) Schott
Gwynne & Wood 890 (EA).

CYMODOCEA CILIATA Ehrenb. ex Aschers.
"4 m. s.w. of island" Gwynne & Wood 918 (EA); Gwynne & Wood 898 (K, EA).

CENCHRUS ECHINATUS L.
Stoddart & Poore 1453 (K, US); Gwynne & Wood 872 (EA, K).

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
Stoddart & Poore 1458 (K, US); Gwynne & Wood 884 (EA).

ERAGROSTIS sp.
Stoddart & Poore 1448 (K, US); Gwynne & Wood 883 (K, EA), 858 (EA).

LEPTURUS REPENS R. Br.
Gwynne & Wood 888 (EA).

STENOTAPHRUM MICRANTHUM (Desv.) C. E. Hubbard
Stoddart & Poore 1454 (K, US); 1470 (K); Gwynne & Wood 871 (K, EA).

CYPERUS AROMATICUS (Ridl.) Mattf. et Kük.
Gwynne & Wood 879 (EA), 892 (EA).

CYPERUS DUBIUS Rottb.
Gwynne & Wood 900, 885 (EA); Stoddart & Poore 1456 (K).

CYPERUS LIGULARIS L.
Stoddart & Poore 1456 (K).

FIMBRISTYLIS CYMOSA R. Br.
Gwynne & Wood 873 (EA).

COCOS NUCIFERA L.
Seen by Stoddart, 1968.

COMMELINA cf. DIFFUSA Burm. f.
Gwynne & Wood 896 (EA).

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AGAVE SISALANA Perr.
Seen by Stoddart, 1968.

CASUARINA EQUISETIFOLIA L.
Gwynne & Wood 891 (K, EA).

LAPORTEA AESTUANS (Gaud.) Chew
Gwynne & Wood 906 (K, EA).

FICUS NAUTARUM Baker
Stoddart & Poore 1455 (K, US).

BOERHAVIA DIFFUSA L.
Gwynne & Wood 877 (K, EA), 886 (EA) (both very young).

BOERHAVIA REPENS L.
Stoddart & Poore 1452, 1474 (K).

ACHYRANTHES ASPERA L.
Stoddart & Poore 1460 (K, US).

AMARANTHUS DUBIUS Mart. ex. Thell.
Gwynne & Wood 860 (K, EA).

PORTULACA OLERACEA L.
Gwynne & Wood 901 (EA); Stoddart & Poore 1471 (K).

CASSYTHA FILIFORMIS L.
Gwynne & Wood 899 (EA).

HERNANDIA SONORA L.
Stoddart & Poore 1445 (K, US).

CLEOME VISCOSA L.
Gwynne & Wood 859 (K, EA); Stoddart & Poore 1442 (K, US).

MORINGA OLEIFERA Lam.
Seen by Stoddart, 1968.

CAESALPINIA BONDUC (L.) Roxb.?
Gwynne & Wood 864 (EA) (only distal part of leaf).

CASSIA OCCIDENTALIS L.
Gwynne & Wood 863 (K, EA); Stoddart & Poore 1462 (K, US).

LEUCAENA LEUCOCEPHALA (Lam.) de Wit
Stoddart & Poore 1446, 1457 (K, US); Gwynne & Wood 888 (K, EA).

SURIANA MARITIMA L.
Seen by Stoddart, 1968.

ACALYPHA INDICA L.
Stoddart & Poore 1459 (K, US); Gwynne & Wood 874 (K, EA).

EUPHORBIA HIRTA L.
Gwynne & Wood 856 (K, EA); Stoddart & Poore 1463 (K).

EUPHORBIA PROSTRATA Ait.
Gwynne & Wood 861 (EA).

PEDILANTHUS TITHYMALOIDES (L.) Poit.
Gwynne & Wood 905 (EA) (hedge plant).

PHYLLANTHUS AMARUS Sch. & Thonn.
Gwynne & Wood 887 (K, EA).

PHYLLANTHUS MADERASPATENSIS L.
Gwynne & Wood 881 (K, EA); Stoddart & Poore 1468 (K, US).

ABUTILON MAURITIANUM (Jacq.) Medic.
Gwynne & Wood 870 (EA) (so det. but sterile, could as well be *A. indicum*).

SIDA PARVIFOLIA DC.
Gwynne & Wood 855 (K, EA); Stoddart & Poore 1451 (K).

THESPESIA POPULNEA (L.) Sol. ex Correa
Stoddart & Poore 1447 (K, US, EA); Gwynne & Wood 868 (K, EA).

CALOPHYLLUM INOPHYLLUM L.
Stoddart & Poore 1444 (K, US); Gwynne & Wood 866 (K, EA).

TURNERA ULMIFOLIA L.
Gwynne & Wood 897 (K, EA); Stoddart & Poore 1464 (K, US).

PASSIFLORA SUBEROSA L.
Gwynne & Wood 876 (K, EA).

CARICA PAPAYA L.
Seen by Stoddart, 1968.

Unidentified Cucurbitaceae
Seen by Stoddart, 1968.

TERMINALIA CATAPPA L.
Gwynne & Wood 907 (EA).

CATHARANTHUS ROSEUS (L.) Don
Gwynne & Wood 857 (K, EA); Stoddart & Poore 1467 (K).

OCHROSIA OPPOSITIFOLIA (Lam.) K. Schum.
Gwynne & Wood 893 (K, EA); Stoddart & Poore 1472 (K, US).

IPOMOEA PES-CAPRAE (L.) R. Br.
Gwynne & Wood 894 (K, EA); Stoddart & Poore 1450 (K, US).

CORDIA SUBCORDATA Lam.
Gwynne & Wood 867 (K, EA), 904 (EA).

TOURNEFORTIA ARGENTEA L. f.
Gwynne & Wood 903 (K, EA).

LIPPIA NODIFLORA (L.) Michx.
Gwynne & Wood 878 (K, EA); Stoddart & Poore 1469 (K, US).

STACHYTARPHETA JAMAICENSIS (L.) Vahl
Stoddart & Poore 1461 (K, US); Gwynne & Wood 862 (K, EA).

CAPSICUM FRUTESCENS L.
Stoddart & Poore 1466 (K).

DATURA METEL L.
Gwynne & Wood 882 (EA); Stoddart & Poore 1441 (K, US).

SOLANUM NIGRUM L.
Gwynne & Wood 879 (EA), 875 (K, EA); Stoddart & Poore 1443 (K, US).

GUETTARDA SPECIOSA L.
Gwynne & Wood 869 (K, EA).

SCAEVOLA TACCADA (Gaertn.) Roxb.
Gwynne & Wood 865 (EA, K) (glabrous).

BIDENS PILOSA L.
Stoddart & Poore 1449 (K, US).

TRIDAX PROCUMBENS L.
Gwynne & Wood 889 (K, EA); Stoddart & Poore 1473 (K, US).

18. GEOGRAPHY AND ECOLOGY OF AFRICAN BANKS

D. R. Stoddart and M. E. D. Poore

Introduction

The two small islands of African Banks are the most northerly of the Amirantes, and are situated on the eastern side of the Amirante Ridge (Baker 1963, 48-51). The ridge surface to the west carries 18-37 m of water. North Island, the larger of the two African Banks, is 275 m long and 45-90 m wide; South Island is 230 m long and 70 m wide. The islands are 2.9 km apart, and only South Island could be visited in 1968. The reef edge lies 450-800 m east of the cays; to the south and west there is a wide area of shoal water with reef patches.

The islands are much smaller, and presumably less stable, than others in the western Indian Ocean that have been considered in these reports. Horsburgh (1809, 127) reported that "they are almost overflowed at high water spring tides", and Coppinger (1883, 219) described one of them (?North Island) as a low flat elliptical cay, built of foraminiferal sand, with "upraised coral sandstone" at its northern end, "grooved and honeycombed into various fantastic shapes". Baker (1963, 50) mentions relict beachrock extending up to 1.1 km north of South Island, indicating considerable shifting of position.

Table 19 lists scientific visitors to the cays. Apart from H.M.S. _Alert_, all have been concerned with the bird fauna. The Percy Sladen Expedition did not call there.

Vegetation

The vegetation of South Island consists of scattered bushes of _Tournefortia argentea_, _Suriana maritima_ and _Scaevola taccada_, all less than 2 m tall, with a single coconut and some gnarled trees of _Tournefortia_ and a sparse and patchy ground cover of grasses, sedges, herbs and vines. Large areas of the ground are quite bare. On the seaward beach crest, which is subject to overtopping by waves, there is a patch of _Paspalum distichum_. The ground cover over the rest of the island consists of patches of two species of _Portulaca_ (a small form, _P. cf. australis_, and a much larger fleshy form), _Boerhavia repens_, _Tribulus cistoides_, _Achyranthes aspera_, _Sida parvifolia_, the sedge _Cyperus ligularis_, and the grasses _Dactyloctenium aegyptium_ and _Lepturus_

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Table 19. Scientific studies at African Banks

Date	Study	Reference
1771	Survey by M. de la Biollière*	
1801	Wreck of H.M.S. Spitfire	
1821	Visit by H.M.S. Menai, Lt. Hay, to North Island	
1882	H.M.S. Alert, R. Coppinger, North Island: birds, general observations	Coppinger (1883); Coppinger and others (1884)
1937 Sept. 8, Nov.	D. Vesey-FitzGerald: sea birds	Vesey-FitzGerald (1941)
1955 July 5, Aug. 17	Viscount Ridley and Lord Richard Percy: sea birds	Ridley and Percy (1958)
1968 Sept. 26	M. E. D. Poore and D. R. Stoddart general observations, plant collection on South Island	This report

*Lionnet (this issue, Appendix) dates their discovery as 1797.

repens. Cassytha filiformis is widespread, and completely smothers some moribund Scaevola bushes at the southern end. The absence of Stachytarpheta may be remarked.

Coppinger (1883, 219), on the island he visited, mentions "scrubby grass and low bushes of the same character as those at Bird Island i.e. Tournefortia", with some juvenile Barringtonia but no other tree species.

Fauna other than Birds

The fauna of African Banks is dominated by birds and marine life; the islands are too small and ephemeral for any large land fauna to have established itself. The Alert collected 11 species of marine Mollusca (Smith 1884), two species of sponge (Ridley 1884), and two crabs, including Coenobita (Miers 1884). Horsburgh (1809, 127) said that African Banks "abound with turtle and aquatic birds, but are destitute of fresh water". Coppinger (1883, 219) found turtle nests but saw no turtle. He also mentions Ocypode. Rothschild (1915) stated that the Giant Land Tortoise was found on African Banks in the seventeenth and eighteenth centuries, but this is certainly an error, unless it refers to an occasional specimen landed from a passing ship.

Birds

The bird fauna is dominated by breeding colonies of terns, particularly Sooty Terns and Noddies.

Shore birds

Ardea cinerea

Two nests in coconuts recorded on North Island by Ridley and Percy (1958, 17).

Migrants

Arenaria interpres

Seen on South Island by Poore and Stoddart, September 1968.

Dromas ardeola

Seen on South Island by Poore and Stoddart, September 1968.

Sea birds

Phaethon aethereus

Sighted from ship off South Island by Poore and Stoddart, September 1968.

Sula sula

Unfledged gannets recorded by Coppinger (1883) and immature wanderers by Vesey-FitzGerald (1941) on 8 September 1937. Booby population said to be negligible by Ridley and Percy (1958).

Sterna dougallii

Breeds on North Island (Ridley and Percy 1958).

Sterna sumatrana

Collected by Coppinger in 1882 (Bowdler-Sharpe 1884, as S. melanauchen). Recorded as nesting on South Island (Vesey-FitzGerald 1941), and as breeding on North Island with a few pairs on South Island by Ridley and Percy (1958). Seen on South Island by Poore and Stoddart in 1968.

Sterna fuscata

Recorded as breeding by Vesey-FitzGerald (1941), and as breeding on North but no longer on South Island by Ridley and Percy (1958), who reported a total population of 43,300 in 1955. Breeding on South Island in large numbers in September 1968.

Sterna albifrons

Recorded by Vesey-FitzGerald (1941).

Thalasseus bergii

Breeding in November on North Island (Vesey-FitzGerald 1941), and again recorded as breeding on North Island by Ridley and Percy (1958). Present on South Island in September 1968.

Anous stolidus

Breeds on the ground with the Sooty Tern (Vesey-FitzGerald 1941). Breeds mainly on North Island, according to Ridley and Percy (1958), but 70 pairs of noddies nesting in bushes on South Island, total population 5900 in 1955. Present in large numbers on South Island in September 1968, mainly in trees and bushes, in contrast to the Sooty Tern which was mainly on the ground.

Anous tenuirostris

Breeding on South Island in September 1968, identified by head colour and by egg pattern, though difficult to distinguish when on the wing from *A. stolidus*. Nesting in a *Scaevola* bush.

Gygis alba

Seen at sea near South Island, probably a stray from Remire.

The sea bird colonies have been much affected by their proximity to Mahé, and the population has seriously declined in recent years. Ridley and Percy (1958) state that the egg export in 1931 was 2000 cases (1.4 million eggs), but that it had fallen by 1954 to 108 cases (75, 600 eggs). The egg industry is now controlled by legislation in the Seychelles.

History and Settlement

The northern islands of the Amirantes were first surveyed in 1771 by M. de la Biollière. H.M.S. *Spitfire* was wrecked on South Island on 21 August 1801, and Lieut. Campbell went in a small boat to Mahé to seek help. He arrived there on 2 September, and the *Spitfire*'s crew was rescued by H.M.S. *Sybille*.

It is unlikely that there has been any permanent settlement on either island. There is a small hut on South Island, used by fishermen and egg collectors, but no-one was living there in September 1968.

African Banks have formed part of the Colony of Seychelles since 1903, and were previously under the administration of Maritius.

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19. PLANTS OF AFRICAN BANKS (ILES AFRICAINES)

F. R. Fosberg and S. A. Renvoize

DACTYLOCTENIUM AEGYPTIUM (L.) Willd.
Southern I., Stoddart & Poore 1434 (K, US).

LEPTURUS REPENS R. Br.
Southern I., Stoddart & Poore 1438 (K).

PASPALUM DISTICHUM L.
Southern I., Stoddart & Poore 1435 (K).

CYPERUS LIGULARIS L.
Southern I., Stoddart & Poore 1432 (K).

COCOS NUCIFERA L.
Seen by Stoddart, 1968.

BOERHAVIA REPENS L.
Southern I., Stoddart & Poore 1431 (K, US).

ACHYRANTHES ASPERA L.
Southern I., Stoddart & Poore 1437 (K, US).

PORTULACA cf. AUSTRALIS Endl.
Southern I., Stoddart & Poore 1439 (K).

PORTULACA cf. OLERACEA L.
Seen by Stoddart, 1968.

CASSYTHA FILIFORMIS L.
Seen by Stoddart, 1968.

TRIBULUS CISTOIDES L.
Southern I., Stoddart & Poore 1436 (K, US).

SURIANA MARITIMA L.
Southern I., Stoddart & Poore 1433 (K, US).

SIDA PARVIFOLIA DC.
Southern I., Stoddart & Poore 1440 (K).

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TOURNEFORTIA ARGENTEA L. f.
Seen by Stoddart, 1968.

SCAEVOLA TACCADA (Gaertn.) Roxb.
Seen by Stoddart, 1968.

20. AN INTRODUCTION OF STREPTOPELIA PICTURATA INTO THE AMIRANTES

C. W. Benson

On 23 September 1967 I. S. C. Parker collected for the National Museum of Kenya, Nairobi, two specimens of the Malagasy Turtledove Streptopelia picturata on St Joseph Atoll, in the Amirantes (see map in Watson et al. 1963, 179). Thanks to R. H. Carcasson and A. D. Forbes-Watson, I have had the loan of them, and they have been donated to the British Museum (Natural History).

Both are sexed as females. They have been compared with material of the grey-headed S. p. picturata (Temminck), of Malagasy, in the British Museum (Natural History), from which in colour they do not differ. But in wing-length (144, 154 mm) they are smaller, Benson (1967, 79) giving a range of 158-170 (mean 166.7) mm for 14 Malagasy females, 165-177 (mean 172.5)mm for 12 Malagasy males. They appear to represent a recent introduction--more likely artifical than natural--from the Seychelles. S. p. picturata was artificially introduced into the Seychelles in the nineteenth century, as recently discussed by Penny (1968, 271). It has there hybridised extensively with the endemic S. p. rostrata (Bonaparte), which in addition to colour-differences, including a vinous head, is smaller. Thus Benson (1967, 79) gives the wing-length of two females as 146, 147 mm only. Those of Parker's two specimens suggest that they do not represent true S. p. picturata but are the result of some hybridisation with rostrata. Some further particulars of them are as follows:

	Larger specimen (wing 154 mm)	Smaller specimen (wing 144 mm)
Weight	135 g	110 g
Irides	pale brown	pale brown
Skin around eye	maroon	-
Bill	horn-grey, base deep maroon	pale horn-grey, soft parts tinged maroon
Feet	dull maroon	dull maroon

Information is very desirable on the extent of this introduction into the Amirantes, where there is an endemic, vinous-headed, subspecies, S. p. saturata (Ridgway), discussed by Benson (1967, 76). Parker had informed me that one of the specimens he collected was with a vinous-headed bird. He was on St Joseph Atoll for less than a day, and so

Atoll Research Bulletin No. 136: pp. 195 - 196, 1970.

cannot provide any information on the extent of the introduction of S. p. picturata. There is no information about saturata beyond that provided from specimens. W. L. Abbott collected it in 1892 on Ile Poivre, slightly to the south of St Joseph, and on Alphonse, 47 miles (76 km) south of the Amirantes proper (Ridgway 1895, 517).

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21. GEOGRAPHY AND ECOLOGY OF TROMELIN ISLAND

France Staub

Introduction

Location

Tromelin Island, a dependency of Réunion Island, is located at 15°52' South and 54°25' East, 390 km east of Antongil Bay, Madagascar, and 480 km north-northwest of Mauritius. Cargados Carajos shoals are about 480 km due east.

Topography

The pear-shaped island measures 1750 meters in length and about three quarters of this distance at its greatest width (Paulian 1955). It consists of coral sand piled up on a coral reef substratum rising to an approximate height of six metres above the high water mark in the northwestern region. The whole structure crowns an abruptly rising submarine cone towering from abyssal depths of about 2500 fathoms. The island profile slopes gently from the highest point in the north-west to the south-east. To the west, a band of raised reef of the "platin" type, met with in some of the Cargados Carajos islets, fringes the beach, passing to the south-east into a belt of coral blocks piled up by the action of heavy swell and breakers driven by the trade winds. On the lee side, sandy beaches occur with formation of small sand dunes. Reefs girdle the island at about 150 metres from the coast and are interrupted by a pass opposite the north-western coast. Access however to the islet is rather difficult and the landing of material for the construction of the meteorological station proved a hazardous operation. The airstrip runs along the long axis of the island.

History

Tromelin Island was first sighted by Captain Briand de la Feuillée on board the Diane in 1722 and was called Sandy Island (Bourde 1934). On the 21st of November, 1776, the Chevalier de Tromelin sailing in La Dauphine and returning from a voyage of exploration to Madagascar rediscovered the island to which he gave his name. He managed to pick up the seven women survivors from the ship L'Utile, wrecked in the vicinity fifteen years before and brought them safely back to Mauritius (Gardiner and Cooper 1907).

Atoll Research Bulletin No. 136: pp. 197 - 209, 1970.

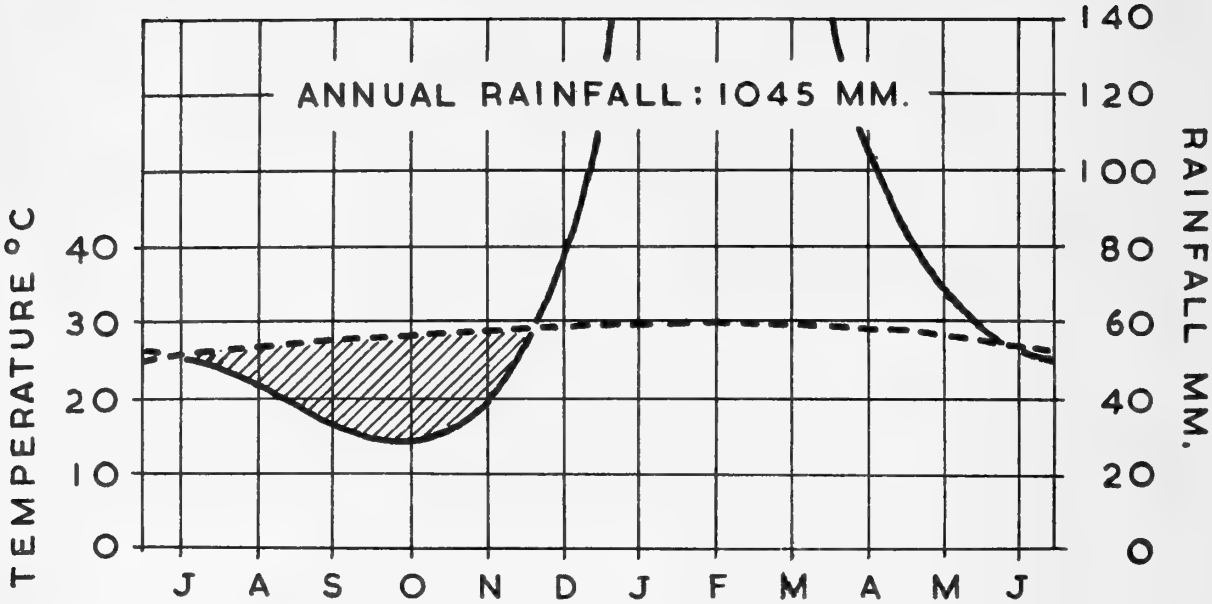

Fig. 9. Ombrothermic diagram for Tromelin

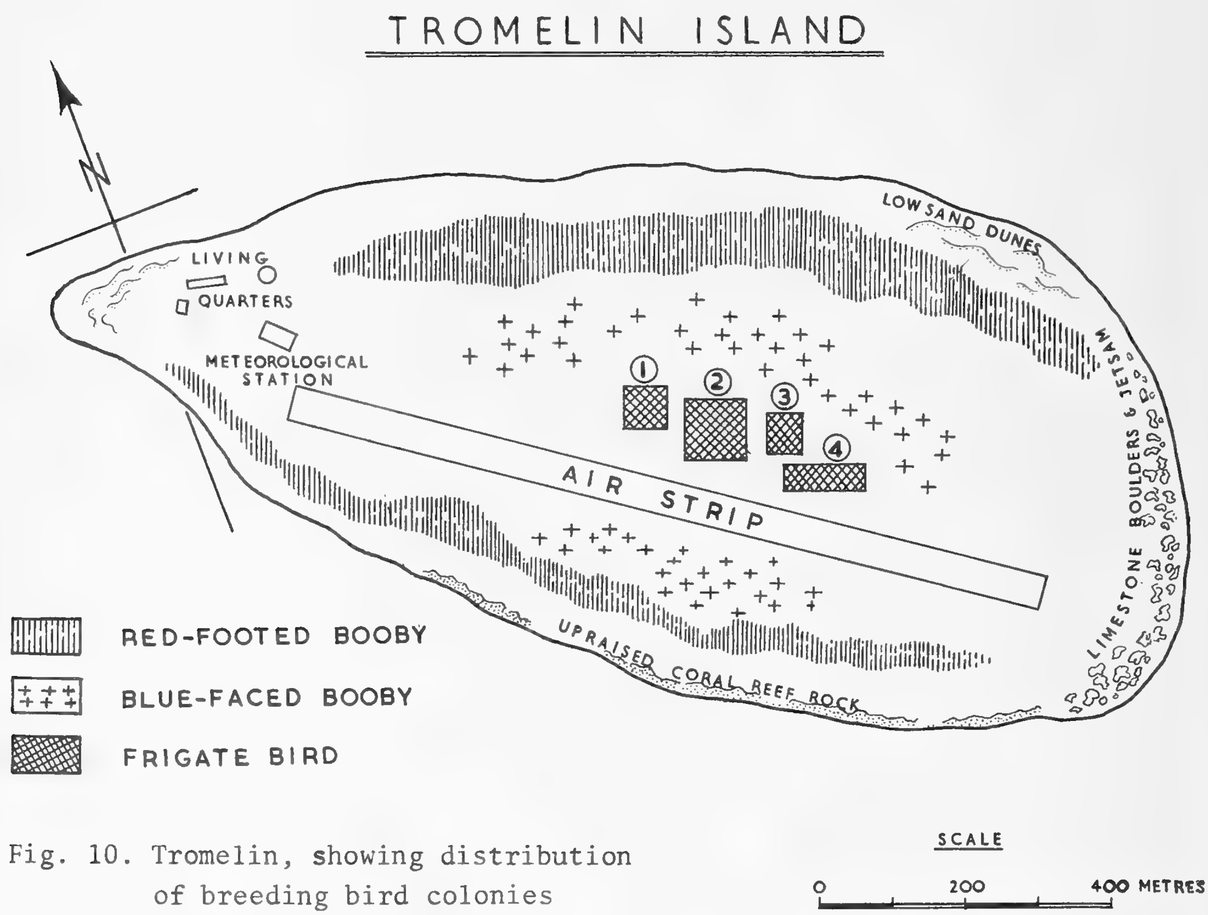

Fig. 10. Tromelin, showing distribution of breeding bird colonies

Climate

In May 1954, a meteorological station was built on Tromelin Island (Platon 1956, Pretceille 1955). It was enlarged later. It is important for the air and sea traffic in this southern part of the Indian Ocean because it is situated in the cyclone zone of the Agalega-Cargados Carajos region where the tracks of cyclones often assume their southern curvature.

The following weather data for the period 1955-1968, obtained from the Meteorological Department, Réunion, through the kindness of Mr. E. Davy, Director of the Meteorological Department, Mauritius, is given in Table 20. An ombrothermic diagram (Fig. 9) is also included interpreting these figures following the method advocated by Bagnouls and Gaussen (1953). A dry cool season extending from July to mid-November prevails, followed by unstable weather with high precipitation during the cyclonic season when the rainfall may exceed 190 mm.

Objectives and description of visit

The aims of the visit were mainly to study, within the limits of the very short time available, the avifauna and vegetation of the islet and to obtain plant material for the Mauritius Herbarium.

We landed from the military plane, which links up Tromelin once every two months with Réunion Island, on the 29th of August 1968 at about 9.30 a.m. and left the next day at 2.15 p.m. having enjoyed the hospitality and comfortable quarters of the meteorological station. In spite of occasional showers passing over with the southeast trade winds, about fifteen hours field work were accomplished. A short 8 mm film on Kodachrome II was made of the nesting bird colonies and a fair amount of photographs both in colour and in black and white were obtained. Ornithological observations and collection of plant specimens were made, with special reference to studies by previous visitors.

Previous studies at Tromelin Island

In November 1953, R. Paulian visited the island, together with a party from Madagascar who came to study the possibilities of building a weather station there. During his two-day visit, he studied the entomological fauna and listed 28 insect species (Paulian 1955). Following the erection of the present station in May 1954, E. Brygoo accompanied the first relieving party in November of the same year. He ringed a hundred Red-footed Boobies and later published his observations on the avifauna (Brygoo 1955). On the 23rd February, 1962, R. O. Morris on board H.M.S. Owen paid a brief visit to the island and subsequently published a report about its avifauna (Morris 1964).

Table 20. Meteorological data, mean monthly figures 1955-1968, Tromelin

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
Rainfall, mm	175.8	146.0	193.3	109.3	68.0	53.3	61.8	46.8	33.2	29.2	50.3	78.1
Number of rainy days per month	12	14	15	12	10	11	12	12	9	7	6	10
Maximum temperature °C	30.0	30.0	29.9	29.3	28.2	26.9	25.9	25.8	26.4	27.3	28.3	29.7
Minimum temperature °C	25.0	25.3	25.1	24.7	23.5	22.1	21.1	20.8	21.3	22.2	23.6	24.8
Pressure at sea level (millibars)	1010.4	1009.5	1010.7	1012.0	1014.5	1016.8	1017.7	1018.1	1017.6	1016.7	1014.4	1012.3
Humidity %	82	82	83	82	80	82	82	82	82	81	82	81
Insolation (hours) (period 1960-1968)	254.5	235.6	244.2	244.4	247.2	234.4	228.7	233.6	250.1	268.5	272.2	292.0

Vegetation

The vegetation consists mainly of two communities as shown in Plate 45. These are: (1) A Tournefortia argentea L. f. shrubbery, one half to one metre high, extending around the island but becoming more scattered towards the centre, that is, along both sides of the airstrip. Towards the north-western end, some Tournefortia trees may reach two and a half metres, (2) an herb-mat consisting mostly of Boerhavia diffusa L. along with scattered colonies of Sida cf. grewioides Guill. et. Perr., with occasional clumps of Portulaca oleracea L. The first plant to colonise the airstrip after weeding is usually the species of Sida mentioned above.

R. Paulian noted the rare occurrence of Achyranthes aspera L. and Ipomoea pes-caprae L. but we did not find the two plants during our short visit. The presence of rabbits recently introduced and now feral, may account for the absence or rarity of these species which are very common on Cargados Carajos 480 km due East, from where birds, wind, and currents could probably transport to Tromelin a supply of seeds or torn strands. About a dozen coconut trees have been introduced and planted along the track to the meteorological station.

Marine fauna

In the short time available, it was not possible to study in any detail the marine fauna. However, tracks left by turtles coming to lay their eggs were quite frequent on the northern beaches and these were said to be mostly green turtles (Chelonia mydas L.) by the staff members. The Hawksbill or Caret (Eretmochelys imbricata L.) was reported to be scarcer. The capture of a Jackfish (Caranx sp.) on hook and line was witnessed on the east coast of the island. The small extent of the lagoon and the rapid deepening of the waters outside the reef would possibly not sustain a richly varied marine life. Pelagic fish would probably be more often encountered.

Fauna other than birds

A few rats were seen hiding in the shade of the Tournefortia bushes during the day. R. Paulian notes that rats (Rattus norvegicus L.) and mice (Mus musculatus L.) were swarming in the southern part of the island in 1953. We found that their number seemed to have been very much reduced, probably due to pest control. There were however quite a number of rabbits all over the island, congregating on the more protected northern side.

Great numbers of hermit-crabs, housed mostly in the shells of Turbo argyrostomus L. were observed at dusk climbing the Tournefortia shrubs. They preyed upon the caterpillars of an insect, Utetheisa pulchelloides Hampson (sensu Jordan 1938), which were themselves actively feeding on leaves of the latter plants.

Insects of Tromelin

The following list records the insects known from the islet and was kindly compiled by Mr. Raymond Mamet, Sugar Industry Research Institute, Mauritius:

Collembola

One undetermined species.

Thysanura

One undetermined species

Orthoptera

Periplaneta americana L. (cosmopolitan)
Blatta orientalis L. (tropicopolitan)
Symploie sp.

Embioptera

Oligotoma saundersi Westw. under bark of *Tournefortia* (cosmopolitan)

Isoptera

Cryptotermes domesticus Hav. (Ceylon, Eastern Indian Ocean and Pacific Ocean up to Panama)

Psocoptera

One undetermined species.

Hemiptera

Creontiades pallidus Ramb. (Continental Africa, Arabia, Madagascar, Mediterranean region)
Stenarus leucochilus Reuter on *Tournefortia* (East Africa, Pemba Islands, Madagascar, Mauritius)
Geocoris insularis China (endemic)
Pictinus pauliani China on *Tournefortia* (endemic)

Homoptera

Igerna bimaculicollis Stål on *Tournefortia* (South Africa, Kilimandjaro, Madagascar)
Pulvinaria tromelini Mamet on *Achyranthes aspera* (endemic)

Coleoptera

Cratopus adspersus Wat. on *Tournefortia* (Amirantes, Chagos, Coetivy, Seychelles, Farquhar, Cargados Carajos, Aldabra, Astove, Cosmoledo, Assumption, Maldives)
Dryotribus mimeticus Horn on dead wood of *Tournefortia* (Florida, West Indies, Galapagos, Hawaii, Adèle and Nyew Tyew Islands, North Western Australia, Chekiang)
Stephanoderes vulgaris Schauf. on dead wood of *Tournefortia* (Madagascar)

Hymenoptera

Pheidole megacephala F. (wide distribution)

Apanteles sp. near *sphingivorus* Granger. A parasite of *Utetheisa* (Lepid.) (Madagascar)

Lepidoptera

Utetheisa pulchelloides Hampson (sensu Jordan 1938) on *Tournefortia* (Africa, throughout Indian Ocean up to Gilbert Isls.)

Loxostege coelatalis Walk. (Ceylon)

Diptera

Sichopogon reginaldi Séguy (endemic)

Ornithoctona plicalilis van Olfers. Host: probably frigate birds (Mauritius, Philippines, New Hebrides, Samoa, Comoros, Madagascar)

Sarcophaga spinosa Villn. (Mediterranean region)

Sarcophaga sp.

Acanthonotiphila scotti Séguy on inflorescences of *Tournefortia* (endemic)

Hippelates longiseta Lamb. on inflorescences of *Tournefortia* (Seychelles, Amirantes, Cargados Carajos)

Siphunculina signata Woll. (Madeira, Cargados Carajos).

Birds

At our time of visit, the bird population of Tromelin Island comprised the following nesting species: the Red-footed Booby, the Masked or Blue-faced Booby and the Great Frigate Bird.

Sula sula rubripes — Red-footed Booby

In 1954, E. Brygoo noted about 200 nesting pairs scattered on the *Tournefortia* bushes, some nesting alongside the Frigates. Of 100 nests inspected, two thirds were occupied by the "white" form, the rest by the "brown and white" form. R. O. Morris in February counted from 150 to 300 individuals. In August 1968, our estimates for the northern half of the island as assessed by the census of occupied nests along 100 x 5 metres of the *Tournefortia* belt were about 300 pairs, compared with 200 pairs for the southern half (Fig. 10). About one third of the observed birds were of the "brown and white" form. It is interesting to note that R. Newton (1958) found about 4 per cent nesting "brown" forms on Ile Albatros at Cargados Carajos in January 1956, in an overall population of three hundred. It is a pity he did not describe this form, as Red-footed Boobies have now disappeared there probably through the depredations of feral cats. Our discovery of a pair of the "white" form roosting on South Island of the Cargados Carajos, in April 1968 might suggest the possibility of recolonisation from Tromelin Island.

As to their nesting habits, the Red-footed Boobies of Tromelin build on top the *Tournefortia* bushes. Nests are two thirds to one metre apart and made up of *Boerhavia* strands with a lining of *Tournefortia* leaves on which the egg is deposited. Brygoo in 1954 found the lining

to have been of Ipomoea pes-caprae leaves. A few egg measurements were taken. In spite of the meagre data obtained, the eggs from the "brown and white" form do appear more slender as shown by the figures given below:

Eggs under "brown and white" form (cm)	Eggs under "white" form (cm)
5.4 x 3.7	6.3 x 4.2
5.2 x 3.7	5.9 x 3.8
5.2 x 3.7	6.2 x 3.7
5.9 x 3.8	6.0 x 4.0
5.9 x 3.8	6.3 x 3.9
5.4 x 3.7	

Colour variation

All the forms of the versatile Red-footed Booby were observed, from naked or fluffy chick that looked as big as its parent, to the two adult forms. It might prove useful to describe its morphology in the light of previous studies made on this same species by Nelson (1968) as occurring in the Galapagos on Tower Island. There they nest, about two metres distant from one another, on the Cryptocarpus shrubs.

At Tromelin the following variations in plumage occur as follows:
Chick: naked, later covered with fluffy white down.
Juvenile: has fledged to chocolate brown form. Bill black, feet dark khaki, eyes clear yellow.
First adult form: Golden brown above, light brown beneath, back streaked with white to all degrees. Rump, tail and underpart of tail pure white. Bill now turned blue. The fleshy part of the head deep pink. Eyes dark brown. The head is tinted a golden hue. The feet now bright red. The gular spot is black.
Second adult form: All white plumage with black primaries. Head suffused with yellow. Fleshy part of the head, bill and feet as of first adult form. The gular spot is velvety black.

The species at Tromelin as described above seems very much like its Galapagos counterpart. It is only in the first adult form that differences occur as to plumage colouration, the Tower Island first adult form being basically brown sometimes with white scapular markings (Nelson 1968). The question whether the first "brown" adult form completes its change to the second "white" adult form is still uncertain. This would require continuous observation of ringed birds in the field for a number of years (Plate 44).

Skins from a "juvenile brown" and a "brown and white" form were prepared and later presented to the Mauritius Institute, Port Louis. Their measurements are given below:

	♀ "juvenile brown" cm	♀ "brown and white" cm
Culmen	8.6	8.7
Tail	20.0	20.0
Wing	37.0	38.6
Tarsus	4.6	4.7
Weight (g)	900	900

Feeding

We noted that the chicks and juveniles regurgitated mainly flying fish when disturbed just as they did at the Galapagos as noted by Nelson. Rich fishing grounds in the vicinity of Tromelin Island exist for these birds and R. O. Morris noticed that they were very active only twenty miles away.

Sula dactylatra melanops "Blue-faced Booby"

This species occupied about fifty nest sites scattered along both the north and south of the airstrip near the central part of the island as shown in Fig. 10. Few eggs were seen, two in a nest being more common than one. About fifteen chicks, just hatched or with down, were being attended by a parent. They were obviously half way through the off period season when breeding is at its lowest. No juveniles were observed and the majority of the colony was apparently keeping to the high seas feeding. As at the Cargados Carajos the peak period of reproduction is probably from November to March as reported by previous visitors.

The "meeting ceremony" of the male relieving a female with chick was filmed while they jabbed at each other before assuming the "parallel standing" illustrated and described by Nelson at the Galapagos. Like the Red-footed Boobies, they were attacked and robbed of their food bolus by the Frigate Birds.

Fregata minor "Great Frigate Bird"

Although both species of the often associated Frigate birds, *F. minor* and *F. ariel iredalei*, have been noted flying over Tromelin Island by R. O. Morris in February 1962, only one species, *F. minor* was noticed just starting its nesting season. On this late August visit in 1968, the males had an extended gular pouch, a few eggs had already been laid.

In the Cargados Carajos *F. ariel iredalei* was observed starting its nesting in late April (Staub and Guého 1968) at the onset of the dry cool season. *F. minor* starts probably later there. The juveniles of both species were nearly all gone from the breeding grounds by April-May the following year. It is surprising that living in identical climates, the *F. ariel iredalei* of Tromelin Island had not set to breeding by late

August, whilst at Cargados Carajos, chicks of this species would already have been well on the way to being fully fledged. During our stay, other groups of Frigates were seen keeping far out at sea but the conspicuous male F. ariel iredalei with its two white side breast patches was not observed with certainty.

The Frigate birds were settled in low Tournefortia bushes in four colonies just north of the central part of the airstrip as shown in Fig. 10. We counted about fifty individuals segregated and associated with Red-footed Boobies into 4 main Colonies, detailed census of which is given in Table 21. A few were gliding low just by the shore, waiting for the homing Boobies which they compelled to regurgitate their food. Red-footed Boobies were the usual victims. Sitting F. minor females had a red ring round their eyes, just as the type of female F. ariel iredalei described by R. Pocklington (1965) from Cargados Carajos. Their bill was also pinkish when compared with the horn-blue colour in the males. The nesting materials were Boerhavia strands and Tournefortia sticks.

Migrant visitors

A small flock of three Whimbrels (Numenius phaeopus ssp.) were seen feeding along the shore on our two-day visit. E. Brygoo (1954) recorded the following three unidentified species: (i) a black and white small wader, often in pairs, (ii) a curlew-like bird running between bushes. This could be a curlew sandpiper, as often seen in the Cargados Carajos, running after insects sometimes far inland. (iii) A noisy bird flying briskly round at dusk, (iv) Brygoo also mentioned that according to staff members a Flamingo was reported to have rested for a night. R. O. Morris (1962) noted the presence of a "few Terns with light grey mantles and black crowns and napes", most probably Roseate terns (Sterna dougalli). These could well have come from the Cargados Carajos where they are known to breed (Table 22).

Settlement

In November 1953, a party from the Meteorological Department of Madagascar visited Tromelin Island to investigate the possibility of building a weather station there. In November 1954 the first station was built and later, additions were made. Nowadays the one-storey high building is one of the best equipped in the Indian Ocean and is doing good service (Plate 2). The first meteorological officer to be in charge, Mr. Jouanney, has imposed rules as to bird preservation which so far have been scrupulously observed, much to the credit of the staff at the station.

Table 21. Fregata minor colonies on Tromelin Island

Colony as shown by map of islet	Associated occupied nests. S. sula rubripes	Number of nests F. minor	Number of nests with egg F. minor	Size of egg of F. minor cm
1	3	11	-	-
2	3	11	4	(8.1 x 4.8 (6.8 x 5.0 (6.9 x 4.82 (7.0 x 4.7
3	1	2	2	(6.7 x 4.5 (6.7 x 4.7
4	9	1	-	-

Table 22. Breeding birds and occasional visitors, Tromelin

	E. Brygoo Nov. 1954	R.O.Morris Feb. 1962	F. Staub Aug.1968
Breeding Birds			
Fregatidae			
Fregata ariel iredalei Lesser Frigate bird	X ?	X	
Fregata minor Great Frigate bird	X ?	X	X
Sulidae			
Sula dactylatra melanops Blue-faced Booby	X	X	X
Sula sula rubripes Red-footed Booby	X	X	X
Migrants and occasional visitors			
Laridae			
Sterna dougalli Roseate Tern	X ?		
Erolia testacea Curlew Sand-Piper	X ?		
Numenius phaeopus Whimbrel			X
Phoenicopteridae			
Phoenicopteros sp. Flamingo	X		

N.B. X identified species
X ? unidentified species

Acknowledgments

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44. Sula sula rubripes: chick with "brown and white" parents

45. Sula sula rubripes: chick nearly fledged to "brown" juvenile form

46. Sula sula rubripes: "brown" juvenile

47. Sula sula rubripes: adult "brown and white" form with few white scapular markings.

48. Sula sula rubripes: adult "brown and white" form with back nearly white

49. Sula sula rubripes: adult "white" form

50. Sula dactylatra melanops: parents with chick

51. Tromelin Meteorological Station

52. Male and four females of Fregata minor with Red-footed Booby in flight

53. Nesting colony of Fregata minor and Sula sula rubripes near airstrip, with Tournefortia thickets and herb-mat vegetation

22. SOME ORNITHOLOGICAL OBSERVATIONS FROM THE WESTERN INDIAN OCEAN

I. S. C. Parker

Introduction

These records were obtained while making a collection of oceanic birds for the National Museum of Kenya (formerly the Coryndon Museum). They were made in September and October 1967 when I accompanied the East African Marine Fisheries Research Organization's vessel Manihine on routine cruise no. 270. This proceeded more or less directly between the points listed below:

		Depart			Arrive
September	14	Mombasa	September	21	Remire (Amirantes)
	22	Remire		22	D'Arros (Amirantes)
	23	D'Arros to St Joseph (Amirantes) to D'Arros (Amirantes)			
	24	D'Arros	September	24	Desroches
	26	Desroches		26	Mahé (Seychelles)
	28	Mahé		28	Coetivy
	29	Coetivy	October	2	Farquhar
October	3	Farquhar		5	Cosmoledo
	6	Cosmoledo		7	Astove
	8	Astove		8	Assumption and Aldabra
	9	Aldabra		12	Latham Island, off the East African coast 97 km south of Zanzibar

Methods

While at sea a discontinuous watch was kept for birds and this covered most daylight hours. Where possible, specimens that came close to the ship were collected. The opportunity was also taken to collect birds on the islands visited, though the time spent was too short to permit more than cursory records to be made. Once a bird had been collected, it was labelled, sealed in a polythene tube, and deep-frozen. The collection was kept in this state until arrival at Nairobi, where specimens were thawed and skinned.

Nomenclature follows Watson et al. (1963).

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List of species seen and/or collected

Oceanites oceanicus (Kuhl)

Two sightings, one at lat. 05°0'S, long. 48°30'E on 19 September 1967, and the other at 04°40'S, 54°20'E, were believed to be this species.

Puffinus pacificus Gmel.

A total of 13 were seen at sea between 4°02'S, 47°40'E and 05°0'S, 52°50'E, but none were seen in the immediate vicinity of Remire Island. They were numerous around D'Arros and St Joseph Atoll and breeding on Fouquet Island of the latter group. They were seen frequently at sea between Desroches and Mahé and between Mahé and Coetivy. They became progressively less numerous en route from Coetivy to Farquhar, and the last was seen at approximately 09°50'S, 51°35'E. Three specimens were obtained at St Joseph, comprising one male and two females. Both females were taken from nesting burrows. Of these, one had recently laid, the egg being collected, but the other did not appear to be in breeding condition, the ovaries being very small. This suggests that non-breeding birds also frequent the nesting grounds. The male collected had enlarged gonads. The nesting ground visited on Fouquet was situated in the midst of a coconut plantation and covered the greater part of the island. Burrows were seldom more than 4 ft (1.3 m) in length or 1 ft (0.3 m) in depth at the deepest point. They were so close together that walking across the colony was rendered difficult. For the greater part, burrow entrances were in the open, but some were concealed under fallen palm fronds or piles of coconut husks. The island's human inhabitants stated that the breeding season was October to December and that annually at least 600 nestlings were taken as rations. They also stated that the continued existence of the nesting colony was entirely due to the complete absence of rats on this particular island. When caught the two specimens taken from burrows made a goatlike bleat. Stomach contents of one comprised a few cephalopod beaks, the second contained a few fish bones, while the third was empty.

Puffinus lherminieri Less.

Several were seen on 23 September 1.6 km north of D'Arros, and a few were seen at sea between Desroches and Mahé. Some 24 were seen south of Mahé within 65 km of the island.

Phaethon lepturus Lacép. and Daudin

A mature male in non-breeding condition was taken at 4°0'S, 44°40'E. Another was seen at 4°25'S, 48°0'E, and two were seen at 4°35'E, 50°0'E. All these birds seen at sea were flying in an easterly direction. On land four were recorded on Remire island, and six on Resource Island of St Joseph Atoll on 23 September. Several were seen at Aldabra. The stomach contents of the one collected were both fish and cephalopod remains.

Sula leucogaster Bodd.

One specimen was secured on Cosmoledo and another on Latham Island. Small numbers were seen off Farquhar, Cosmoledo and Aldabra atolls and around Astove. They were numerous at Latham Island where a small number were nesting. Young were present in all stages from newly hatched to fully fledged. Some birds were brooding. Both specimens taken were females in nonbreeding condition. The stomach of one was full of gastropods.

Sula sula (Linn.)

This species was common around Cosmoledo, Astove, Assumption and Aldabra where it was by far the most numerous booby. It was also recorded at sea at approximately 4°25'S, 49°0'E, in company with Sooty Terns Sterna fuscata. One immature was collected at the latter position, two more at sea off Farquhar Atoll, and two mature males were taken at Cosmoledo. One of the latter was in breeding condition. Both mature birds had empty stomachs, but all three immatures contained fish remains.

Sula dactylatra Less.

Several immatures were seen at sea at approximately 04°25'S, 50°20'E, of which one was collected. Several mature birds were also seen at sea at 4°40'S, 51°30'E, of which one was also collected. On both occasions they were accompanied by many Sterna fuscata. Off Astove Island three matures were seen and they were very numerous around and on Latham Island. As with Sula leucogaster they were breeding, and in all stages from newly laid eggs to fully fledged young. This was the most numerous of the two boobies. Nests of both species were intermixed. The mature male taken at Latham Island had enlarged gonads, another two collected at sea were not in breeding condition. The stomach of the Latham Island specimen contained some twenty cephalopod beaks, one of the other had cephalopod beaks and fish bones, while the third was empty.

Fregata minor Gmel.

This species was seen on all islands visited except Mahé. Single birds were occasionally seen at sea between 4°0'S, 44°40'E and Remire Island. A mature male in full breeding condition was taken 320 km west of Remire. An immature was taken on St Joseph. Stomachs of both were empty.

Fregata ariel (Gray)

Seen on all islands except Mahé with F. minor. None were seen at sea, but this might be due to misidentification with the latter.

Ardea cinerea Linn.

A total of three were seen at Remire Island, 15 on St Joseph Atoll, one on Goelette Island, Farquhar Atoll, three at Astove, of which two were recently fledged, and they were numerous at Cosmoledo and Aldabra.

Bubulcus ibis (Linn.)

This species was recorded from Farquhar Atoll, Cosmoledo, Astove and Aldabra. On Goelette Island, Farquhar, a small colony of four nests in a stunted Casuarina tree contained six fully fledged young. A mature female was collected, not in breeding condition, with stomach content of grasshoppers, flies, a centipede (Liogryllus sp.) and many spiders (Latrodectus sp.) The specimen almost lacks any buffy plumes. Its wing-length is 235 mm.

Egretta garzetta (Linn.)

This species was common on the reefs of Cosmoledo and was seen at Astove, Assumption and Aldabra.

Butorides striatus (Linn.)

Common on all the islands of St Joseph Atoll in the Amirantes, and seen on all islands visited in the Farquhar and Aldabra groups except Assumption. The specimen collected, a female, was obtained at St Joseph and was not in breeding condition.

Perdix sp.

A large partridge was observed on Coetivy, but it was not identified specifically. It was almost certainly an exotic introduction.

Charadrius leschenaultii (Less.)

Seen in small numbers on all islands visited except Desroches, Mahé and Coetivy. A female was collected at Remire.

Squatarola squatarola (Linn.)

Recorded in pairs from all islands except Desroches, Mahé and Coetivy. None collected.

Calidris testacea (Pallas)

Small numbers were observed on Farquhar Atoll, and on all of the Aldabra group. A female collected on Goelette Island, Farquhar, was in very poor condition with several engorged ticks, as yet unidentified, which were collected. Its stomach contained fine insect fragments.

Crocethia alba (Pallas)

Small numbers on all islands visited except Desroches, Mahé and Coetivy. The specimen, a male, was obtained at Resource Island, St Joseph Atoll, Amirantes. Its stomach contents were insect fragments and white grit.

Arenaria interpres (Linn.)

Seen in all islands except Coetivy in parties of 6-50. The species was by far the most common palaearctic migrant. Many were seen at sea on 21 September. All were flying due east overtaking the ship. They flew as widely scattered individuals rather than in flocks. Three specimens collected were taken on D'Arros Island in the Amirantes. The stomach contents included small crustacea, grit and small insects.

Actitis hypoleucos (Linn.)
Eight were seen on Menai Island, Cosmoledo.

Tringa nebularia (Gunn.)
Six were seen on the reefs of St Joseph Atoll, Amirantes.

Numenius phaeopus (Linn.)
Whimbrel were seen on Remire in the Amirantes, Farquhar, Cosmoledo and Astove. On these islands they were common. The specimen collected, a female, was obtained on Menai Island, Cosmoledo.

Dromas ardeola (Payk.)
Twelve were seen on St Joseph reef, Amirantes, of which three were collected. A flock of about 100 was seen at Menai Island, Cosmoledo. Gonads of those collected were small, and stomach contents were whitish crabs.

Thalasseus bergii (Licht.)
About 200 were seen on Remire Island in groups of up to six. Several were seen on Goelette Island, Farquhar Atoll, and a few at Cosmoledo and Aldabra. Four specimens were taken at Remire. Of these none were in breeding condition; all contained fish remains in their stomachs.

Sterna dougallii Montagu
Six were seen on Goelette, Farquhar Atoll, from which two were obtained. The ovaries of one specimen were small, and stomach content nil.

Sterna albifrons (Pallas)
One specimen of this species was seen flying eastwards mid-way between Mombasa and Remire. Several small groups of up to 6 and one of about 50 were recorded on Goelette Island, Farquhar. A flock of more than 100 was seen on the eastern shore of Assumption. All six specimens taken were from Goelette; they were not in breeding condition, and the stomach contents were entirely fish remains.

Sterna fuscata Linn.
This species was by far the most frequently sighted bird on the cruise. It was seen in large flocks, small parties and singly every day at sea except 11 October (between Aldabra and Latham Island). On the eastward leg from Mombasa to Remire they were sighted at least once every two hours of observation and often very much more frequently. The species occurred around every island visited. On Goelette Island, Farquhar, a large breeding colony was visited. Several thousand young birds, all more than half fledged and the majority fully fledged, were present and indicated the end of the breeding season. Outstanding were the large number of dead and dying juveniles, apparently affected by starvation. Apparently a large number of noddies Anous stolidus had also nested on this island, but fledging had taken place earlier. Bailey

(1968) makes a similar observation on Desnoeufs Island, Amirantes. There were fewer immature noddies on the ground, but they outnumbered Sterna fuscata in the air. Both species were very tame. The Farquhar islanders take at least 1000 eggs annually from this ternery and probably many more. Another large colony was recorded on Wizard Island, Cosmoledo Atoll. Here all had fledged, and there were very few young about. There was little evidence of the massive mortality recorded from Farquhar. A total of four specimens were taken, one from Remire and three from Farquhar. None were in breeding condition. All stomach contents were fish remains.

Sterna anaethetus Scop.

This species was very numerous on Remire Island, Amirantes, and was seen on D'Arros and St Joseph, Amirantes. It was not recorded elsewhere. A total of four was obtained on Remire. Of these one had slightly enlarged testes, the others were inactive. Stomach contents were entirely fish remains.

Sterna sumatrana Raffles

One specimen was seen on Resource Island, St Joseph Atoll, and 50 were seen on Goelette, Farquhar Atoll. Two specimens were collected on Goelette, one of which, a female, was in breeding condition. Stomach contents were entirely fish remains.

Gygis alba (Sparrm.)

Recorded as very common on Remire, D'Arros, St Jospeh and Desroches (Amirantes) as well as on Cosmoledo, Astove and Aldabra. A number were seen 65 km out to sea between Mahé and Coetivy. All four specimens were taken on Remire. All were in breeding condition. Stomach contents of all were fish remains in which a Sardinella sp. was recognised.

Anous stolidus (Linn.)

This species was recorded from every island visited, and was often seen up to 65 km from land. It was particularly numerous around the Amirantes and was breeding on Goelette Island, Farquhar, as described in the section on Sterna fuscata above. All three specimens were taken at Remire. One was a male and two were females, none obviously in breeding condition. In two the stomachs were empty and one contained small fish.

Anous tenuirostris (Temm.)

Only recorded from Remire Island, where it was by far the most common bird. On the western side of the island it was present in such numbers that the eight specimens were taken with a shot intended for one. It is of interest that all eight were females with very small ovaries. Though more likely coincidence, it is possible that the species exhibits some segregation of sexes when not breeding. The stomachs of all but one contained small fish.

Streptopelia picturata (Temm.)

Some were seen on D'Arros and St Joseph (Amirantes) but were nowhere numerous. The majority of those seen were associated with the small patches of native vegetation. Two females were taken. These are discussed by Benson (1970a).

Geopelia striata (Linn.)

This species is common on North Island, Farquhar Atoll. One male was collected in breeding condition.

Foudia madagascariensis (Linn.)

This species was the only passerine seen on Remire Island, and was numerous on D'Arros, Resource and St Joseph Atoll. One taken on Remire was in non-breeding dress with only a few red feathers on the head, and one from St Joseph was in breeding plumage with a little olive on the nape.

Passer domesticus (Linn.)

This introduced species is very common on D'Arros, Resource and St Joseph Atoll. A female was collected at the latter locality.

Cisticola cherina (Smith)

This species was numerous on Menai Island, Cosmoledo Atoll, and on Astove. Three males were collected on Menai Island, and two males on Astove. For a full discussion of specimens of this and the next two species, see Benson (1970b).

Nectarinia sovimanga (Gmel.)

The one species was recorded on Menai Island of Cosmoledo Atoll, Astove, Assumption and Aldabra, and appeared to be the only Nectarinia species on these islands. Ten specimens of N. s. buchenorum (Williams) were collected on Menai Island and Astove.

Zosterops maderaspatana (Linn.)

This species was observed on Astove (only six specimens seen) and on Aldabra, where it appeared numerous. The two specimens collected were obtained on Astove.

Corvus albus Muller

No attempt was made to secure specimens of this species. However a pair was recorded on Menai Island, Cosmoledo, another on Astove, six individuals were seen on Assumption, and at least 24 during the short stay on Aldabra.

Weights

When it did not interfere with other scientists' activities specimens were weighed before freezing. It was not possible to weigh every specimen, but the following table gives the records made; weights

were also recorded of all the specimens of Cisticola cherina, Nectarinia sovimanga and Zosterops maderaspatana. These are included in Benson (1970b).

Species	Sex	Weight (g)		
Puffinus pacificus	♂	325		
	♀	335	350	
Phaethon lepturus	♂	350		
Sula sula	♀	1750		
Bubulcus ibis	♀	320		
Butorides striatus	♀	180		
Arenaria interpres	♂	83	107	
	♀	100		
Dromas ardeola	♀	285	295	
Thalasseus bergii	♂	325	345	350
	♀	350		
Sterna albifrons	♂	45	50	56
	♀	42	45	
Sterna fuscata	♂	190		
	♀	170	180	
Gygis alba	♀	102		
Anous stolidus	♂	160		
	♀	195		
Anous tenuirostris	♀	110	115	120
Geopelia striata	♂	56		
Foudia madagascariensis	♂	15	16	
Passer domesticus	♀	24		

Discussion

Observations and collections made at sea were too infrequent to permit any statistical analysis of results. Similarly the time spent ashore was too short to permit any certainty of complete records. Thus the apparent absence of a species in this list from any area or island cannot be taken to mean that it did not occur.

Of the 18 species of sea birds seen only 8 were seen more than 64 km from land. These were Oceanites oceanicus, Puffinus pacificus, Phaeton lepturus, Sula sula, S. dactylatra, Fregata minor, Sterna fuscata and S. albifrons.

The outward voyage from Mombasa to Remire was associated with a strong south-easterly wind and an eastward flowing current (counter-equatorial). The greatest variety of pelagic bird sightings and the highest number were made on this stretch. S. fuscata was particularly common. It appeared, subjectively, that at least 90 per cent of birds seen on this leg were flying east or southeast.

The return journey from Aldabra to Latham Island coincided with a westward-flowing current and somewhat reduced southeasterly winds. Bird sightings were very infrequent and comprised a few S. fuscata only. On 11 October no sightings were recorded at all. It thus appeared that much more birdlife was associated with the counter-equatorial current.

The only palaearctic migrants seen at sea were Arenaria interpres. As already stated, these were flying due east toward Remire. The greatest number of such species (8) was seen in the Aldabra atoll, which is the southernmost island on the cruise and the nearest to Africa. The flight direction of A. interpres and the distribution of species suggest that palaearctic migrants might reach the Amirantes, Seychelles and Aldabra Islands from the African mainland to the west and not from Asia. If such is the case sea crossing is greatly reduced.

Moreau (1940) was of the opinion that Sula leucogaster did not occur on Latham Island and that S. dactylatra was the only species present there. The current data prove conclusively that both species inhabit and breed on Latham Island.

The land birds collected are better discussed by workers in a position to compare them with other collections because of their evolutionary and taxonomic interest. They have been discussed by Benson (1970).

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Summary

Observations are presented of 40 bird species recorded on a one-month cruise in the western Indian Ocean during September and October 1967. The cruise included stops in the Amirantes group, Seychelles, Aldabra group, and Farquhar.

At sea the greatest number of bird sightings was associated with the counter-equatorial current.

It is suggested that palaearctic migrants may reach the Amirantes, Seychelles and Aldabra groups from the African mainland.

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APPENDIX: NAMES OF THE ISLANDS

J. F. G. Lionnet

The coral islands of the western Indian Ocean are nearly all dependencies of the Seychelles. Among the exceptions are Agalega, which belongs to Mauritius, the Gloriosa Islands, which belong to the Malagasy Republic, and the islands of the British Indian Ocean Territory. Of these latter, Desroches, Farquhar and Aldabra were until 1965 part of the Seychelles, and the Chagos Archipelago was formerly administered by Mauritius. As the islands have generally been named after their discoverers or early explorers, their names recall the early history of the Indian Ocean.

Denis and Bird Islands

Denis Island bears the name of Denis de Trobriand, who took possession of it in the name of the King of France in 1777, while in command of the flute *L'Etoile*. Bird Island, better known in the Seychelles as Ile aux Vaches, has been named after the numerous sea birds, mainly Sooty Terns, which breed upon it. Its alternative name refers to the vaches marines, or dugongs, which were formerly found there.

Platte, Coetivy and Agalega

Platte (the correct orthography should be Plate) owes its French name to its topography. It is indeed so flat and low that it is difficult to locate, especially during rough weather. It was discovered and named by Lieutenant de Lamperiere, of the goelette *La Curieuse*, in 1769.

Coëtivy bears the name of the Chevalier de Coëtivy, who sighted it on 3 July 1771, while in command of the flute *Ile de France*. Agalega or Galega derives, according to E. de Froberville, from Portuguese words meaning "the Galician". This island is therefore reported to have been named after the Galician navigator João de Nova, who is believed to have discovered it in 1501.

The Amirantes

The Amirantes, which figured on early Portuguese charts as the Ilhas do Almirante, or Admiral's Islands, are believed to have been named after Vasco da Gama, the celebrated Portuguese navigator, who is

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believed to have sighted them in 1502, soon after acceding to the rank of Admiral, during his second voyage in the Indian Ocean. They were explored in 1771, the southern islands in January of that year by the Chevalier du Roslan of the corvette _L'Heure du Berger_, and by the Chevalier d'Hercé of the corvette _L'Etoile du Matin_; the northern islands by the Chevalier de la Biollière, also of the corvette _L'Etoile du Matin_, in November of the same year. They were formally taken possession of, in the name of France, on 7 September and 5 October 1802, by the Sieur Blin, who sailed from the Seychelles on the goelette _La Rosalie_ for that purpose.

The origin of the name of the African Banks or Bancs Africains is not known. They were discovered and named Ilots Africains in 1797 by Admiral Willaumez, then a Capitaine de Vaisseau in command of the frigate _La Régénérée_.

Eagle Island, known in Seychelles as Rémire, bears the name of an English ship which visited it in 1771. The origin of its French name is not known. Eagle was visited by the Chevalier de la Biollière in 1771.

Daros bears the name of the Baron d'Arros, Marine Commandant at the Ile de France (Mauritius) from 1770 to 1771.

Poivre bears the name of Pierre Poivre, the famous "Peter Pepper" and Intendant of the Ile de France (Mauritius) and Bourbon (Réunion) from 1769 to 1772. It was visited by the Chevalier du Roslan, but was named by the Chevalier de la Biollière, in 1771.

Boudeuse and Etoile are believed to have been named after the two ships of Bougainville's famous voyage round the world, from 1766 to 1769. They were explored and named by the Chevalier du Roslan in 1771.

Marie Louise was visited and named by the Chevalier du Roslan in 1771. It was the fourth island located by that explorer in the course of his voyage in the Amirantes. The origin of the name is not known.

Desnoeufs, or Desneuf, which means "one of the nine", is believed to owe its name to the fact that it is one of the nine main islands of the Amirantes. It was, however, only the fifth island located by the Chevalier du Roslan, during his voyage in the Amirantes, in 1771, and who named it Ile des Neufs. On the other hand, according to E. de Froberville, the name should be "des Noeuds"; the origin of this latter name is not known.

Desroches has been named after the Chevalier des Roches, the Governor of the Ile de France (now Mauritius) and Bourbon (now Réunion) from 1767 to 1772. It was explored by the Chevalier de la Biollière in 1771.

Alphonse, St François and Bijoutier

Alphonse bears the name of its discoverer, the Chevalier Alphonse de Pontevez, of the frigate *Le Lys*, who visited it on 28 January 1730.

St François, which was discovered on the same occasion, was named presumably after the religious feast of 29 January, which is that of St François de Sales.

The origin of the name of the third island of the group, Bijoutier, is not known.

St Pierre, Providence and Farquhar

St Pierre bears the name of a ship, that of Captain Dechemin, who visited the island on 6 June 1732.

Providence was named "La Providence" by the crew of a French frigate, *L'Heureuse*, which was wrecked on a neighbouring bank in 1769, and who managed to reach the island.

The Farquhar Islands were formerly called Juan de Nova (or Jean de Nova), after João de Nova, the Galician navigator. Their names were changed in or about 1810, when they were renamed after the first British Governor of Mauritius, Sir Robert Townsend Farquhar. The islands were visited by the Chevalier de Pontevez in 1730.

The Aldabra Group

Cosmoledo, according to d'Avezac, bears the name of an unknown Portuguese navigator. The two main islands of the group, Menai and Wizard, have been named after two ships of Captain Moresby, who visited them in 1822. The group was sighted by Captain Nicolas Morphey, of the frigate *Le Cerf*, on 13 August 1756.

The name Astove, according to d'Avezac, derives from the Portuguese words "As Doze Ilhas", meaning the twelve islands, which he claims was originally the name of the Farquhar islands but which was tranferred in error to Astove. Astove was visited by Captain Lazare Picault, of the tartane *L'Elisabeth*, and Captain Jean Grossin, of the boat *Le Charles*, in 1742, during their exploration of the Seychelles.

Assumption Island (Assomption in French) was discovered by Captain Nicolas Morphey on 14 August 1756, and named presumably after the religious feast of the next day.

The origin of the name Aldabra is uncertain. It has been said to derive from the Arabic "al-Kadhra", meaning "the green", and also from "Aldaraba", a type of door knocker the same shape as the atoll. According to d'Avezac the atoll should be named Ilha da Area, meaning

Sand Island, though this hardly seems appropriate. C. Elgood (Seychelles Bulletin, 6 April 1967) claimed that Aldabra could derive from the Arabic "al-Dabaran", which means the five stars in Taurus, more particularly the brightest of the group. If the first of these derivations is accepted, it could be attributed to the fact that the large lagoon on Aldabra produces a green reflection in the sky above the atoll, which can be seen for miles out at sea. Aldabra was sighted by Captain Lazare Picault and Captain Jean Grossin in 1742.

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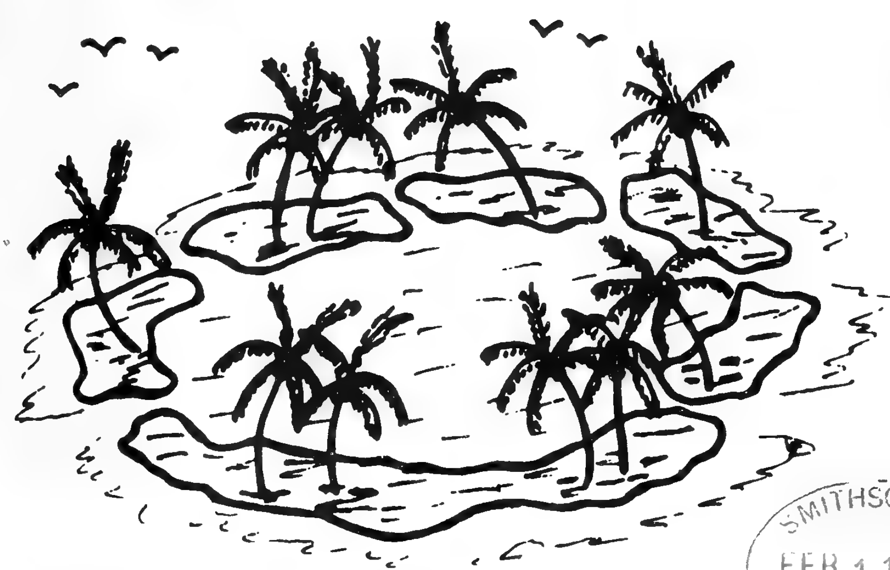

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CARBONATE SAND CAYS OF ALACRAN REEF, YUCATAN, MEXICO: SEDIMENTS

by Robert L. Folk and Augustus S Cotera

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CARBONATE SAND CAYS OF ALACRAN REEF, YUCATAN, MEXICO: SEDIMENTS

by Robert L. Folk [1] and Augustus S Cotera [2]

ABSTRACT

Carbonate beach sediments have sorting values averaging about .40ϕ, and subtidal sediments are poorly sorted with sorting values averaging 1.1ϕ. *Halimeda* dominates the coarser sands and coral becomes more abundant in finer sands. Roundness and polish are caused by abrasion, and are greatest where rate of supply is lowest and wave energy is highest.

INTRODUCTION

Alacran Reef lies about 70 miles north of the Yucatan Coast, and is the best-developed atoll of a series of carbonate highs rising from about 150 feet of water that line the edge of the Campeche Bank. Literature and general morphology are reviewed in Folk (1967) and will not be duplicated here. A very thorough work on the grain size and composition of submerged sediments of the reef, and a description of a core through it have been published by Bonet (1967); Bonet and Rzedowski (1962) discussed cay vegetation in detail. Hoskin (1968) investigated mineralogy of the muds, and Logan et al. (1968) described in detail the geology and evolution of the Yucatan platform.

Alacran Reef (Fig. 1) has a well-developed windward reef on the eastern side, and a central lagoon heavily choked with a maze of coral. All seven sand cays occur on the lee rim of the reef. Sediments of Isla Perez, the most complex cay, have been discussed by Folk and Robles (1964). This paper concerns grain size distribution, composition and roundness of the sediments of the other six cays.

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GRAIN SIZE DISTRIBUTION

Previous Work

There is a great deal of grain size data on Recent carbonate sediments; for examples, see Vaughan (1918), Bramlette (1926), Thorp (1936a, 1936b), Todd (1939), Stark and Dapples (1941), Emery, Tracey and Ladd (1954), Carroll (1957), McKee, Chronic and Leopold (1959), Maxwell, Day and Fleming (1961), Tracey, Abbott and Arnow (1961), Emery (1962), Maxwell, Jell and McKellar (1964), Fosberg and Carroll (1965), Guilcher (1965).

Unfortunately the great bulk of this data is presented in the form of histograms, based on 1ø sieve intervals; often, no statistical parameters are computed--and if they are, the obsolete Trask measures of 1930 and 1932 (Median, S_0) are generally used. These measures are inadequate, because they measure only the central 50% of the size distribution, whereas--if one wishes to discriminate between depositional environments--the most critical region is in the tails (Folk, 1966). Furthermore, in all geologic environments, both sorting and skewness values strongly depend on the mean grain size, and without scatter plots to show the interrelationship of the several size parameters, a great deal of potential interpretation is lost.

More embracive phi statistics and/or size parameter scatter plots have been used for carbonates by Folk (1962), Hoskin (1962, 1963, 1966), Folk, Hayes and Shoji (1962), Folk and Robles (1964), Stoddart (1964, 1966), Swinchatt (1965), and Bonet (1967). Because of the difference in manner of data analysis, only the grossest comparison may be made between these recent papers and the older histogram-oriented results.

It has been commonly noted that beach sediments are well sorted and that submerged sediments are not (Todd, 1939; Maxwell, Day and Fleming, 1961, Emery, 1962; Maxwell, Jell and McKellar, 1964) though there are some exceptions (Swinchatt, 1965). But inasmuch as sorting is a close function of average grain size, this postulate cannot be satisfactorily verified with size sorting plots which show that sediment of the same given mean size is really more poorly sorted underwater than on the beach (Folk, 1962; Folk and Robles, 1964; Stoddart, 1966). To be useful in paleogeographic studies of limestones a quantitative line should be established between the two environments on size sorting plots, and the amount of overlap assessed.

Considering the beach environment itself, it is important to examine the role of wave energy in mean size and sorting--e.g. how do size and sorting differ on protected versus exposed beaches. It is generally true that sand on leeward or lagoonal beaches is finer than that on exposed, windward beaches (Carroll, 1957; Folk, Hayes and Shoji, 1962; Folk and Robles, 1964; Fosberg and Carroll, 1965; Folk, 1967). However, in sediment of the same mean size there apparently is little difference in sorting between protective or exposed beaches (Folk, 1962,

1967). Samples taken low on the beach are coarser than those high on the beach (Todd, 1939; Emery, 1962; Folk, 1967) and this is also true for terrigenous sands (Otvos, 1965).

One must also evaluate the strong control that type of organism and its breakage mechanism exerts on size/sorting plots (e.g. Folk and Robles, 1964; Stoddart, 1964; Fosberg and Carroll, 1965).

Because skewness varies from dominantly positive to dominantly negative as a function of mean grain size, blanket statements of skewness, divorced from an attendant grain size, are rather meaningless. However, most carbonate beaches do tend to be symmetrical to negatively skewed, i.e. they have a tail of coarser grains (Stark and Dapples, 1941; McKee, Chronic and Leopold, 1959; Folk, Hayes and Shoji, 1962; Folk and Robles, 1964; Fosberg and Carroll, 1965).

This degree of skewness is also generally true of terrigenous beach sands (e.g. Mason and Folk, 1958; Ellis, 1962; Friedman, 1961, 1965, 1967; Sevon, 1966; Tanner, 1966; Martins, 1967; and others). However, Todd (1939) found about equal numbers of (+) and (-) skewed sands in her study of carbonate beaches, as did Pilkey, Morton and Luternauer (1967).

The predominant negative skewness can be caused either by (1) winnowing of fines by wave action, in effect amputating the fine tail of a normal distribution; or (2) addition of a stray coarser mode, resulting from inclusion of large fragments which can roll easily on a smooth, firm sand beach.

ALACRAN RESULTS

Methods

Samples collected on the cays of Alacran were divided into three groups: beach surface samples, buried layers beneath the beach, and submerged samples. In the beach surface samples, the top layer of the beach was sampled, generally a one inch cube at the top of the sand, midway in the wave swash zone or foreshore. At each locality a trench was dug; if layers deeper in the trench appeared to be a different grain size or composition than the surface layer, they were also sampled and designated as "buried samples". Where differences did exist, the deeper layers were generally coarser grained than the surface sample. Again a one-inch cube of sand was taken, usually at a depth of between two to eight inches from the surface.

Submerged samples were taken by wading out from shore, and were all in three feet of water or less. Sampling here was necessarily cruder, and the surface material was scooped up in a small bottle from a spot one or two inches in diameter.

Samples were analyzed using screens spaced at 1/2ϕ intervals, following the method described in Folk and Robles (1964). Though sieve sizes are different from hydraulic sizes (see Maiklem, 1968, for an excellent discussion), sieve sizes best correspond with size measurements made microscopically on ancient calcarenites.

Mean size and sorting

Geologic meaning of the size parameters can best be visualized on the plot of size versus sorting. Grain size must be examined in two ways: (1) viewed as a whole, with samples from all six cays combined, and (2) viewed individually for each cay. Viewed in combination (Fig. 2) the beach surface samples range from fine calcarenite to fine calcirudite, or approximately 2.5ϕ to - 1.0ϕ (.18 to 2.0 mm). This plot does not include the beach ridges of coral sticks. Sorting varies from very well sorted to moderately well sorted, two-thirds of the samples falling in the range of σ_I = .30 to .60ϕ. The average sorting value is about .40ϕ (well sorted). There is a weak association between mean grain size and sorting, such that the finest sands are best sorted (at a mean of 2.5ϕ, σ_I = .25ϕ), while sands of mean sizes 1.0ϕ and coarser have σ_I of about .50ϕ. The attainment of best sorting at 2.5ϕ is also true of other carbonate beach sediments, of most terrigenous beach sands, and of many dune and river sediments. This is the size of sand most easily moved by both water and wind currents.

On this plot, submerged samples are clearly (possibly fortuitously well) segregated from the beach surface samples, by a σ_I boundary of about 0.7ϕ; using this boundary, only 5% of the samples are misclassified. The submerged samples are medium to coarse calcarenite (0ϕ to 2ϕ). Sorting values are much poorer, two-thirds of the samples ranging in σ_I from about .8 to 1.4ϕ (moderately to poorly sorted), and averaging 1.1ϕ. Submerged samples were taken from areas of bare sand, and also from areas that were vegetated with turtle grass; some of the turtle grass areas are finer (1.5-2ϕ) and show poorest sorting of all (because of a relatively high carbonate mud content) but other "grass" samples show size and sorting similar to the submerged bare sand areas. A roughly arcuate trend associates mean size with sorting for the bare sand samples. Bonet (1967) found σ_I values of over 1.0ϕ for submerged samples; Stoddart (1966) in the Maldives also found a σ_I of 1.0 best separated beach from submerged samples.

Buried beach samples overlap the beach-surface samples and submerged samples, with intermediate sorting values, σ_I generally running between .40 and 1.0ϕ (well to moderately sorted). The reason for this overlap is that sediment on that beach surface becomes buried as the water level rises (i.e. at higher tides) and deposits a new layer of sediment on top. During this period, the older layers are of course submerged--thus take on the grain size character of submerged sediments--and are not subject to the winnowing and sorting action that takes place on the overlying "beach" surface.

In the initial analysis of the data the size parameters for each island were plotted using color coding. It became evident that East and West Desterrada, which are located at the north end of the reef, formed coincident trends on the size/sorting plot, and therefore could be treated together. Similarly, Pajaros and Chica, at the south end, were a homogeneous group and could be combined. Desertora, Desaparecida, and Perez (data from previous work) each possessed their peculiar trend.

With the exception of Desaparecida, each island or island-pair shows a similar arcuate inverted-V trend on the size-sorting diagram, with poorest sorting at some intermediate grain size; but when all islands are combined on one graph each trend is shifted right or left so that complete overlap occurs and they blend to produce an almost formless triangular blob. Thus the trends for the individual islands (Fig. 3) have been summarized in Fig. 3a, where the shifts in trends are evident. Moral: do not combine too much data when trying to evaluate relationships!

On these five islands as well as on Isla Perez, the cause of the arcuate trend appears to be mixing of two main constituents: relatively coarse flakes of Halimeda at - 0.5 to 0.5ϕ (0.7-1.4 mm), and fine grit rich in coral at about 1.5ϕ-2.5ϕ (.18- .35 mm). The trends are not as sharp on these islands as they were on Isla Perez, because wave abrasion has worn the particles more severely to produce a complete range of intermediate sizes. Abrasion masks the inherent breakage modes of these skeletal particles and thus blurs the size/sorting curve.

Isla Desaparecida data shows little or no systematic trend. As will be shown later, Desaparecida shows a great difference in composition from the other islands of Alacran atoll, inasmuch as it has very little coarse Halimeda, and all skeletal particles are very well rounded. Hence the very different size/sorting pattern, because particles no longer show the size modes that result from their inherent breakage mechanism.

Skewness and kurtosis

Considering all six cays except Perez, beach surface samples have skewness averaging - .01, with s = .18 (Fig. 4). The central two-thirds of the skewness values actually range between - .18 and + .14. Curves classified as "near-symmetrical" form 49% of the samples, "positive-skewed" 22%, and "negative-skewed" 29%. Only 14% show strong skewness beyond + .30 or - .30. Thus beach surface samples hover close to normality, and in this respect are unlike terrigenous beaches which are usually negative-skewed.

Of the submerged and buried samples, mean skewness is - .09, with s = .29. Two-thirds of the samples range between - .38 and + .21. "Near-symmetrical" curves form only 27%, "positive-skewed" 24% and "negative-skewed" 49% of the samples. Fully 39% of samples show extreme

skewness values beyond $\pm$ .30. Thus submerged and buried samples are less normal, show a wider range of extreme skewnesses and are dominantly coarse-skewed (tail of coarse grains).

More instructive is a scatter plot of skewness as a function of mean size (Fig. 5). Here there is a quite strong association in a sinusoidal trend, similar to that shown by sands and gravels on Isla Perez (Folk and Robles, 1964). Essentially normal curves occur at positions of prominent modes in the sediment, e.g. about Mz = + 0.4ϕ (dominantly Halimeda flakes), and about Mz = 2.1ϕ (subequal coral grit and Halimeda). Starting with the coarse mode (+ 0.4ϕ), samples become more positive skewed as the finer mode is added, until maximum positive skewness of about + .20 is reached at a mean size of about 1.0ϕ; these samples consist of about 3/4 coarse mode and 1/4 fine mode. At about 1.3ϕ, where both modes are equal, the curves pass the .00 skewness point; then as more fine mode is added to dominance, the curve becomes negative-skewed, reaching maximum negative skewness of about - .30 at a mean of 1.7ϕ (one-quarter coarse mode and three-quarters fine mode). Although there is considerable scatter about this trend, given the mean size, one can predict skewness to within $\pm$ .20 Sk_I units of the theoretical value.

The skewness trend is only mildly shown by the beach surface samples, but is much more extreme in buried and submerged samples; both reach maxima and minima of skewness at the same mean size value, but the absolute values of skewness are more extreme in the submerged and buried samples.

Submerged and buried samples tend to be negatively skewed because all consist dominantly of rather fine beach sand, to which a few coarser fragments have been added, such as coral sticks, larger unbroken Halimeda flakes, etc.

Kurtosis in this suite of samples showed little of interest. For beach-surface samples, mean K_G' was .520, and two-thirds of the values fell between .48 and .57; for buried and submerged samples, mean K_G' = .518 and the two-thirds range was .46- .57. Plots of skewness vs. kurtosis revealed that most "very leptokurtic" values were from submerged samples and were also strongly skewed (either + or -), but a plot of Mz vs. K_G' showed only a buckshot scatter.

Grain composition

Sediments of Alacran Reef consist entirely of carbonates, and those of the cays apparently consist entirely of contemporary skeletal fragments--there is no reworked beachrock, oolite or carbonate aggregates. However, submerged sediments, deeper than 150' - 200', contain small amounts of spar-cemented aggregates, probably broken from the cemented old carbonate mound underlying the reef (Hoskin, 1963, p. 53).

Gravels, found in quantity only on the exposed south coasts of Isla Perez and Pajaros, consist very largely of coral-sticks rubble, made up of finger-like joints of Acropora cervicornis, the staghorn coral. A few scattered blocks of more massive corals (Montastrea, Diploria, or Acropora palmata) litter the seaward side of Islas Perez and Pajaros. Relationships of the coral gravel have been described previously on Isla Perez (Folk and Robles, 1964) and also hold true for Pajaros.

Composition of the sands was determined by examining thin sections of samples representative of the complete grain size range on each island. In each thin section a count of 100 points was made; sample-to-sample variation warrants no further precision. Samples were also examined with binocular microscope for general appearance of the fragments. Point count data shows that beach sands of Alacran consist predominantly of two constituents. Porous white flakes of Halimeda, a calcareous green alga, dominate the coarser sands while coral grit is abundant in the finer sands. Only Isla Desaparecida departs from the following summary; it will be discussed later.

Results of this and other work show that the abundance of any given organic component in a sample (such as Halimeda or coral, for example) is not only a matter of ecology or productivity of the organism, it is also very strongly a function of grain size of the sediment. Beaches supplied with the same assemblage of organic materials will have very different compositions depending on whether they are fine sands or coarse sands. In particular, on Alacran, the relative proportion of Halimeda and coral is markedly influenced by grain size of the sediment.

Thus Halimeda forms approximately 80% of the sand with a grain size of -1ϕ (2 mm); about 65% of the 0ϕ (1 mm) sand; and about 45% of the sand between 1ϕ and 2.5ϕ (0.5 to 0.18 mm). By contrast, coral forms only 5% of the -1ϕ (2 mm) sands, 15% of the 0ϕ (1 mm) sand, and reaches 25% at 1ϕ (0/5 mm), and 45% at 2ϕ. These relations are shown in Fig. 6.

As an overall grand mean, Halimeda makes up 52% and coral 28% of the samples. Of the other constituents, mollusc fragments average almost 10% but drop off rapidly below 1.5% (.35 mm); coralline algae average about 5%; Peneroplid foraminifera about 3%; and all others 3%. The latter group includes a few small foraminifera, pink Homotrema rubra crusts, echinoid fragments, gorgonian spicules, pellets, and unknown skeletal debris. The close relationship of organic composition with grain size is shown in Fig. 7, a graph of the (Halimeda)/(Halimeda plus coral) ratio plotted against mean grain size of the sample. In general if the mean grain size is - 0.5ϕ (1.4 mm) the proportion is 9:1 Halimeda over coral. There is a linear decrease in this ratio with diminishing size, such that at 2ϕ (.25 mm) the ratio is 1:1.

Isla Desaparecida differs greatly from the other cays, which all fall along the same composition vs. size trend line. For a given grain size, Desaparecida is much higher in coral and lower in Halimeda, the H/H + C ratio ranging from 1:1 in the coarser sands to 1/4:1 in the finer ones.

An explanation for this difference may be that Desaparecida is a temporary islet, which is nonexistent much of the year, when it consists of a submerged bar shifting, current-swept sand. Thus there is nothing to provide protection for the contemporary growth of Halimeda plants, and indeed we have found no Halimeda tracts off the coast of this islet.

On all the islands, it is noticeable that the coarse Halimeda flakes tend to have their pores empty and look "fresh" while the finer Halimeda fragments generally have their pores filled by growth of a mass of needles. Presumably this difference means that the larger flakes have only recently been liberated by death of the plant, while the smaller flakes are much older fossils which have been worn down to relatively small size and thus have been internally cemented. Moreover, on Desaparecida even the few coarser Halimeda fragments have their pores largely filled, thus are probably derived from long-dead plants and not from contemporary ones.

A correlation matrix was calculated using the I.B.M. 1620 computer at Allegheny College. Analysis of the composition and mean grain size data quantitatively substantiated relationships suggested from the hand-drawn scatter plots. Omitting the samples from Isla Desaparecida (because of the totally different trend of Halimeda and coral vs. grain size), the expected relationships were verified (see correlation network diagram, Fig. 8). Samples of fine grain size are much higher in coral ($r = + .90$) and lower in Halimeda ($r = - .73$); consequently coral and Halimeda show a strong negative correlation ($r = - .72$). Molluscs tend to be associated with the coarser sands ($r = - .51$) and of course also avoid coral ($r = - .62$); coralline algae are similar to mollusc fragments in occurrence. Other constituents either are present in such small amounts (average under 5%) or show such weak correlations that they are not worth placing in the diagram.

Abundance and Grain Size of Halimeda in Other Areas.

Halimeda is so abundant on Alacran reef, and its occurrence is so closely tied with grain size, that it is instructive to examine its occurrence in other modern carbonate areas to see if the same size relationships obtain.

In the Caribbean and the Gulf of Mexico carbonate areas, Halimeda is extremely abundant as reported by Steers (1940a, 1940b), and Steers, Chapman and Lofthouse (1940) in Jamaica; Van Overbeek and Crist (1947) stress its overall great abundance as a sediment constituent, with

particular examples from Puerto Rico; Thorp (1936a), Ginsburg (1956), and Swinchatt (1965) describe its occurrence in south Florida; Daetwyler and Kidwell (1959), Cuba; Purdy (1963a, 1963b) and many earlier workers report its abundance in the Bahamas; Hoskin (1962, 1963, 1966) and Folk and Robles (1964) show its abundance on Alacran and it is also common on protected areas in the vicinity of Isla Mujeres, Quintana Roo (Folk, Hayes and Shoji, 1962; Folk, 1967). Stoddart (1964) describes its occurrence on Half-Moon Cay, British Honduras.

In the Pacific area, Halimeda seems much less common as a beach sediment, although it is important in many lagoonal areas. It has been reported by many authors, two examples being David and Sweet (1904), Funafuti; and Emery, Tracey and Ladd (1954), Bikini. Hoskin (1963, p. 54) tabulates abundance in eleven reef areas, and found that Halimeda makes about 30-40% of submerged sediments. Hillis (1959) shows worldwide distribution maps of the various species.

We have shown that on Alacran, as a generalization, most Halimeda tends to be concentrated in the coarse sand to granule range, i.e. about 0.5 mm to 4 mm (1ø to - 2ø) as measured by sieving. Data from other areas shows similar results. For example, inspection of Bramlette's (1926) data shows Halimeda most abundant in the - 1 to + 1ø range. McKee, Chronic and Leopold (1959) gave the average size as - 1ø, and Emery (1962) had it most abundant in the coarsest sand. Folk and Robles (1964) showed that it dominated Isla Perez sediments between - 1ø and + 1ø, and Hoskin (1966) in Alacran lagoon pinnacle sediments found Halimeda to be about - 1ø (2 mm). Stoddart (1964) in a detailed study found Halimeda had a mode about 0ø, and maximum - 2ø. Folk and Robles examined the manner of breakdown, individual "leaves" or segments being - 2 to - 2ø, the average size of Halimeda after beach abrasion about 0ø, and the ultimate size on abrasion, 10ø (1 μ) dust or needles. Upchurch and McKenzie (1968 oral presentation) found in Bermuda that it generally broke to 0 to 1ø grains. In contrast, Maxwell, Jell and McKellar reported Australian Halimeda most common in the 1 to 2.5ø grade, making it about one-fourth the typical grain size of Halimeda reported from elsewhere. Fosberg and Carroll (1965) place it in the - 2 to - 3.5ø grade, much coarser than other workers.

Roundness and Polish

Estimating the amount of abrasion in carbonate environments is difficult. First, no good standard scale of roundness is available, like those established for quartz sand grains or pebbles, although Pilkey, Morton, and Luternauer (1967) set up a scale for abraded mollusc fragments, Fosberg and Carroll (1965) used a petrographic abrasion scale based on a particular spiny foraminifer, and Bathurst (1967) used a scale developed for use with terrigenous grains. Second, carbonate grains from various organisms have a tremendous range in fragility, shell architecture, etc., and break and abrade by grossly different mechanisms. Third, the original shape of many particles (e.g. foraminifera) is

already round, and one must try to separate true abrasional rounding from inherent roundness. Fourth, the rate of supply (crop renewal rate) greatly differs from one organism to the next, and from one locality to the next, so there is a complex problem of roundness being affected both by varying rate of supply, and varying rate of abrasion. Fifth, fragments may be abraded by wave action, by wind abrasion during periods spent in dunes, and by activities of organisms that may either break their prey into angular pieces like crabs, or pass it through their gut, perhaps rounding them by solution or abrasion. Sixth, because most carbonate particles are so soft and round so rapidly, rapid local variations are to be expected between, for example, dune vs. beach vs. submerged carbonate sediments, or between windward and leeward sides of islands, or between freshly dead skeletons and those reworked by erosion of older sand banks on the cays, where grains had been abraded in previous cycle. Some of these factors have been discussed by Wentworth and Ladd (1931), Swinchatt (1965) and Moberley (1968).

Despite these difficulties, the writers have made an estimate of roundness of the carbonate grains. Roundness was estimated under a binocular microscope at magnifications of 9X to 45X. The only satisfactory way to do this is to allow direct sunlight to fall on the particles as they lie loosely scattered on a dull black background; in this way polish can be seen best. Samples were analyzed in random order to prevent operator bias.

The best indicator of abrasion is coral grit, because (1) it is usually distributed throughout all grain sizes, (2) it is found in most modern tropical carbonate sediments, not only in the Caribbean but almost everywhere else, (3) all fragments started out as sharply angular pieces broken from the larger masses (no problem of "original roundness"), (4) the "crop renewal rate" is fairly slow--not as rapid as Halimeda, (5) it is durable, not so fragile and apt to be rebroken after being rounded as does Halimeda, (6) it takes and holds a good polish, and (7) it forms equant particles that are grossly similar in shape to quartz particles. Therefore most of the following data on roundness is based on examination of coral grit.

Halimeda shows abrasion fairly well, but is very fragile unless the pores are filled with aragonite, and the rapid growth rate means that beaches are continually supplied with a flood of freshly broken material. It generally does not take a good polish because it is too soft and friable. Some attention can be paid to the broken but polished and edge-rounded pieces of mollusc shells. Peneroplid foraminifera also take good polish but are unsatisfactory for roundness estimations because of their disc-like original shape. The following table is a summary of the data, made by binocular evaluation of the bulk unsieved samples, not by counting individual grains.

E. Desterrada: Subangular to subround, uniform.
Polish slight, most on E and N coast.

W. Desterrada:	Subround to subangular, trifle more round on NW shore. Polish slight to good, uniform geographically.
Desaparecida:	Round to subround, uniform. Polish uniformly good.
Desertora:	Subround to subangular, trifle more round on E half. Polish moderate.
Perez:	Mostly angular, but subangular on N and E coasts. Mostly dull, but polish moderate on NE coast.
Chica:	Subangular, slightly more round on NE. Polish slight.
Pajaros:	Angular to subangular, most angular on Cuello de Coral, roundest midway on E coast and on N coast. Mostly dull, but polish moderate midway down E coast.

From this table it is evident that in this area of relatively low wave energy and high organic productivity, there is considerable variation in roundness and polish from island to island and even from one part to another of the same island. Here on Alacran, polish and roundness definitely go hand-in-hand, and polish is undoubtedly the result of abrasion not chemical processes.

The variation in degree of abrasion can be explained as the result of the interplay of two main variables, (a) rate of supply and (b) wave energy. The main factor explaining gross roundness differences from one island to another is the rate of supply. Those islands close to living reefs and supplied, especially during storms, with large amounts of freshly-broken reef debris, contain the most angular sands (Fig. 9A), thus Perez and Pajaros have the dullest and most angular sand. Isla Desaparecida, on a broad sand flat with no flourishing coral reef or *Halimeda* flats nearby, and also on the part most to leeward of the entire Alacran atoll, has the best rounded and polished sand (Fig. 9B). The other islands are intermediate in reef proximity, and intermediate in roundness and polish. Locally on the islands, rate of supply also plays a role. This factor is markedly shown on Perez and Pajaros, which both have extensive ridges or pavements of broken coral-sticks (*A. cervicornis*) on their south, west and north sides, and both have mostly dull, angular sand where the coral sticks ridges are most abundant. On both islands, coral stick pavement is lacking on the east coast, and on both islands, greatest roundness is reached on the east coast, farthest away from the occurrence of coral-stick ridges or pavements. The coral-stick ridges are usually near living reefs, hence there is always an easily replenishable supply, and they continually break down to provide a new fresh source of angular coral grit.

A second factor is wave energy. In most of the islands, the best rounding and polish occurs on either east-facing or north-facing coasts. It is probably not a coincidence that the most frequent summer winds are from the east, and the strongest common winter winds are from the north. Doran (1955), Emery (1962), Folk, Hayes and Shoji (1962) and Fosberg and Carroll (1965) mention the general polish and roundness of carbonate sands on exposed beaches in other areas.

These relationships are presented in the idealized diagram, Fig. 10, where roundness is presented as a function of both wave energy and rate of supply, and various Mexican carbonate areas are placed on it. Pilkey and Luternauer show no relationship of roundness with wave energy in their area; I would assume it is because in their area, all wave energies fall within what I would call the "high" range (open Atlantic).

CONCLUSIONS

1. Beach surface samples are "well-sorted" (σ_I = .40) and submerged samples are poorly sorted (σ_I = 1.1); they are clearly differentiated on a size-sorting scatter diagram, by a boundary line of $\sigma_I = .70\phi$.

2. Individual islands have distinct inverse-V trends of sorting as a function of grain size. This is caused by the mixture of organisms and the varying amount of abrasion. The position of the inverse-V trend shifts from one island to another.

3. Skewness is a sinusoidal function of mean grain size. Beach sediments average nearly normal, while submerged samples are more non-normal with a dominance of negative skewness.

4. Over half of the beach sand is composed of *Halimeda*, and coral makes up more than one-fourth. *Halimeda* dominates the coarser sands, and coral is most abundant in fine sands, thus there exists a very strong correlation between grain size and composition of these sands. In many areas of the world, *Halimeda* tends to break to grains of about 1 mm modal diameter.

5. Roundness in carbonates is best estimated by studying only coral fragments. On Alacran, roundness and polish are both the results of abrasion, and are highest where the rate of supply is low and/or the wave action is greatest.

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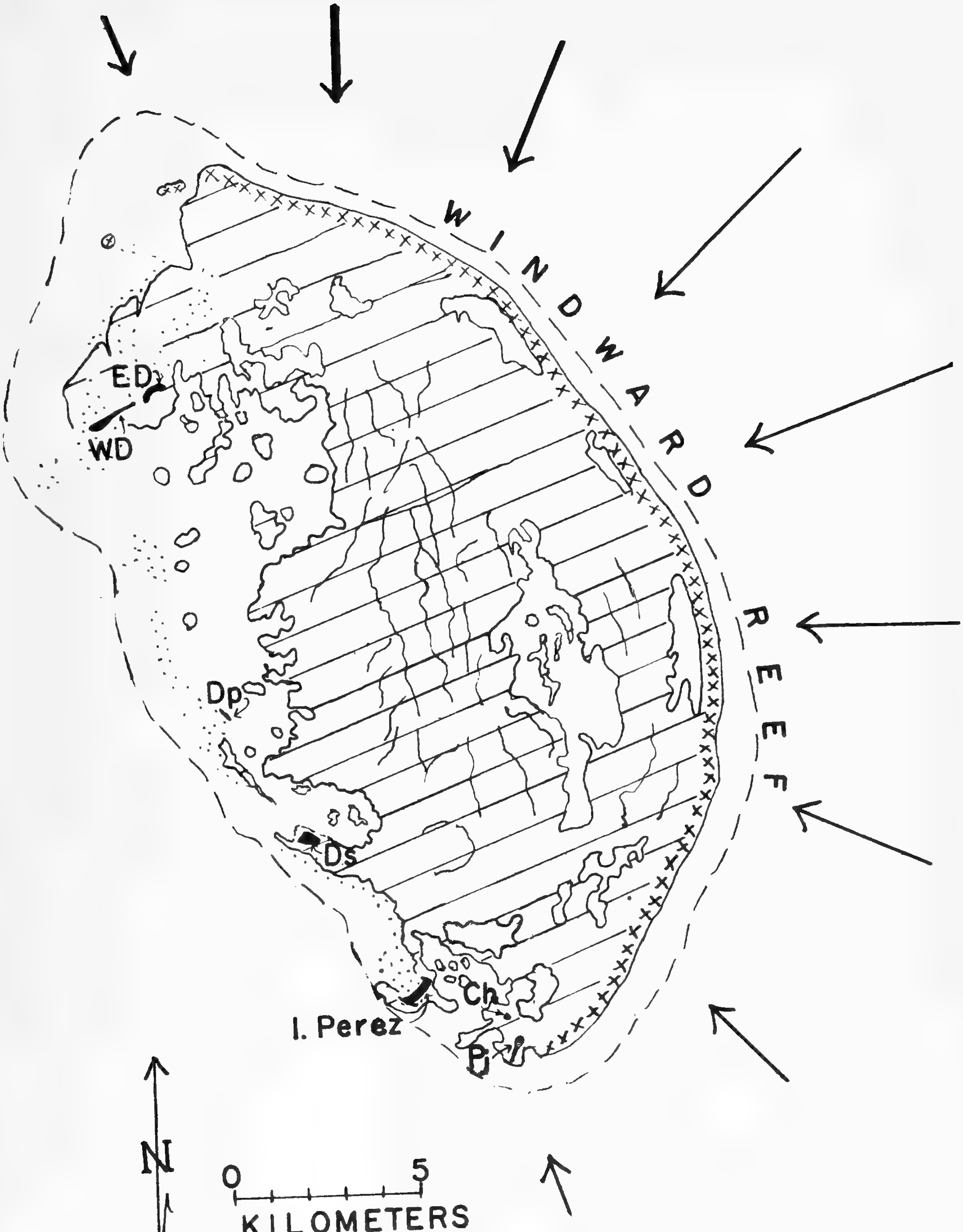
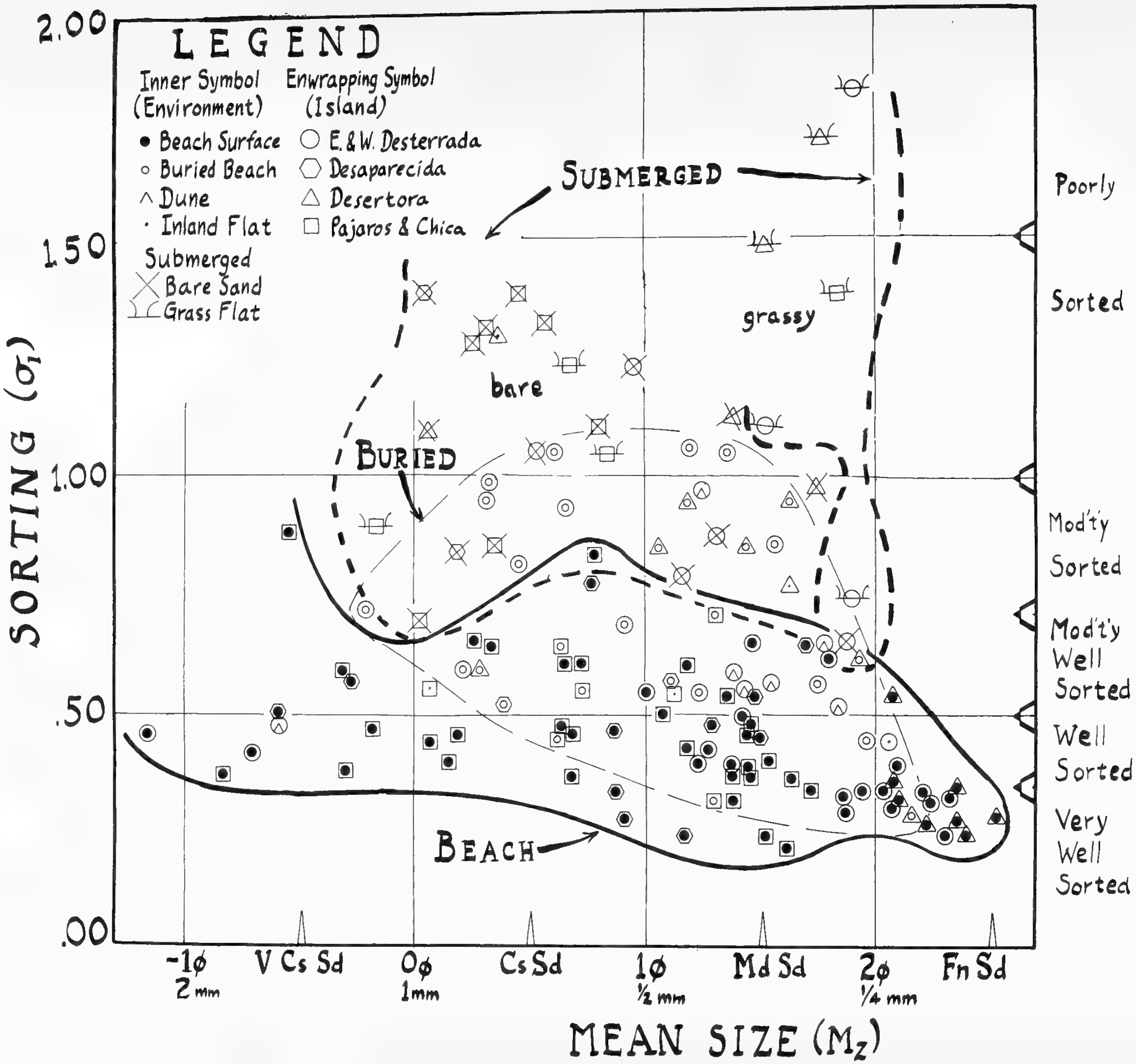
Figures 1-10

Figure 1. Alacrán Reef, Yucatán. Arrows show wind direction, with length proportional to wind frequency and arrow thickness proportional to velocity. The windward side of the atoll is marked by a continuous massive coral reef (X pattern), and the lagoon is largely filled in with anastomosing coral ridges and patches. The six sand cays of this report all lie on the lee side of the atoll and are designated as follows: ED, WD, East and West Desterrada; Dp, Desaparecida; Ds, Desertora; Ch, Chica; and Pj, Pajaros. Sediments of Isla Perez were discussed earlier.



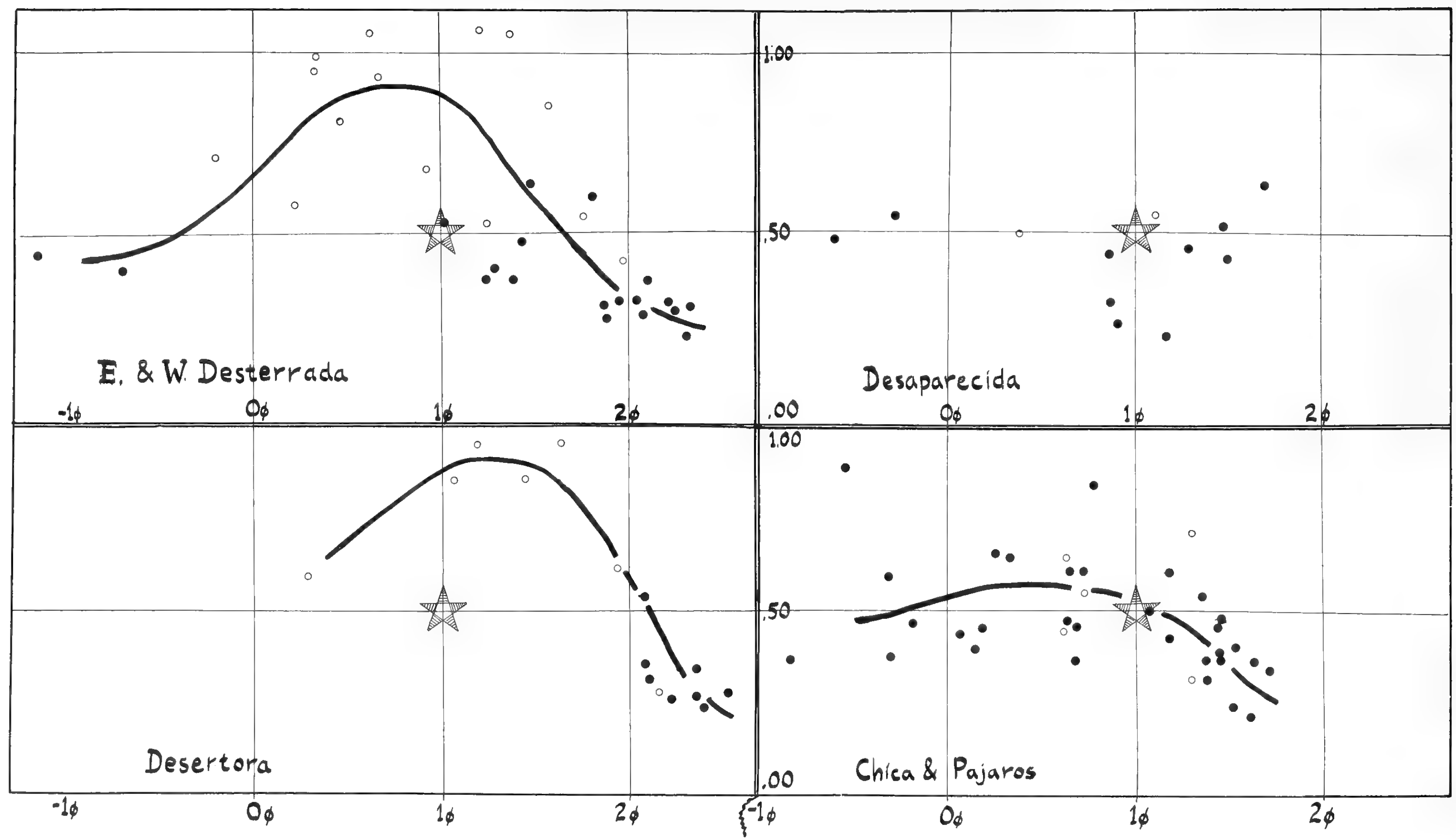
ALACRÁN REEF

Figure 2. Scatterplot of Mean Size (M_z) vs Sorting (σ_I). Beach surface samples (solid circles), the field enclosed by a solid heavy line, almost all have sorting values better than 0.70ø and average .40ø. Submerged samples, enclosed by a heavy dashed line, almost all have sorting values worse than .70ø, averaging 1.10ø; those on grassy bottoms tend to be finer than those on bare, current-swept bottoms. Buried samples within the beach (open circles, all enclosed by a light dashed line) overlap the two fields.



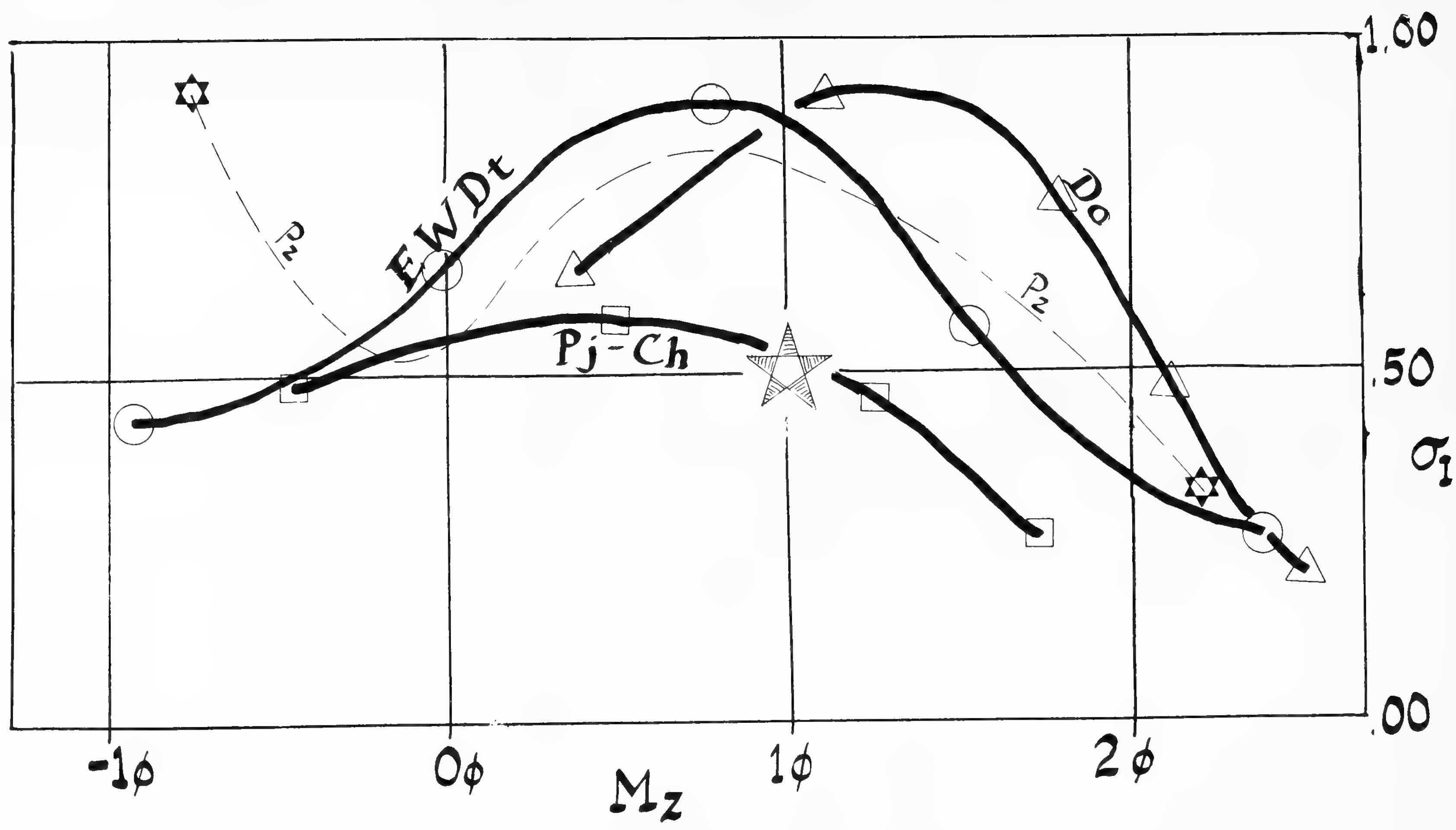
LEGEND
Inner Symbol (Environment)
• Beach Surface
∘ Buried Beach
^ Dune
· Inland Flat
Submerged
Bare Sand
Grass Flat
Enwrapping Symbol (Island)
E. & W. Desterrada
Desaparecida
Desertora
Pajaros & Chica
SUBMERGED
BURIED
BEACH
bare
grassy
SORTING (σ_1)
2.00
1.50
1.00
.50
.00
MEAN SIZE (M_z)
-1ϕ 2 mm
V Cs Sd
0ϕ 1 mm
Cs Sd
1ϕ ½ mm
Md Sd
2ϕ ¼ mm
Fn Sd
Poorly Sorted
Mod'ty Sorted
Mod'ty Well Sorted
Well Sorted
Very Well Sorted

Figure 3. Size vs sorting trends for four related island-groups, showing beach-surface samples (solid circles) and buried samples in the beach (open circles). Each island-group has its own size-sorting trend, but this trend differs in position from one island-group to another though maintaining a roughly similar arcuate form. The star provides a constant reference point for all graphs. Chica and Pajaros have the coarsest sediments (trend shifted to left) and Desertora has the finest sands.



E. & W. Desterrada
Desaparecida
Desertora
Chica & Pajaros
1.00
.50
.00
-1φ
0φ
1φ
2φ

Figure 3a. Trends of Fig. 3 combined in one graph to show the shifts; trend of Perez data (Pz) added. The minimum of best sorting at about 1.5-2.5ϕ represents material that is composed of about half *Halimeda* and half coral grit, and this is also the most mobile size for sand. The other minimum σ_I value occurs at about -1ϕ to 0ϕ and represents modal concentrations of nearly pure *Halimeda* segments.



1.00
.50
.00
σ1
-1φ
0φ
1φ
2φ
Mz
EWDt
Do
Pj-Ch
Pz
Pz

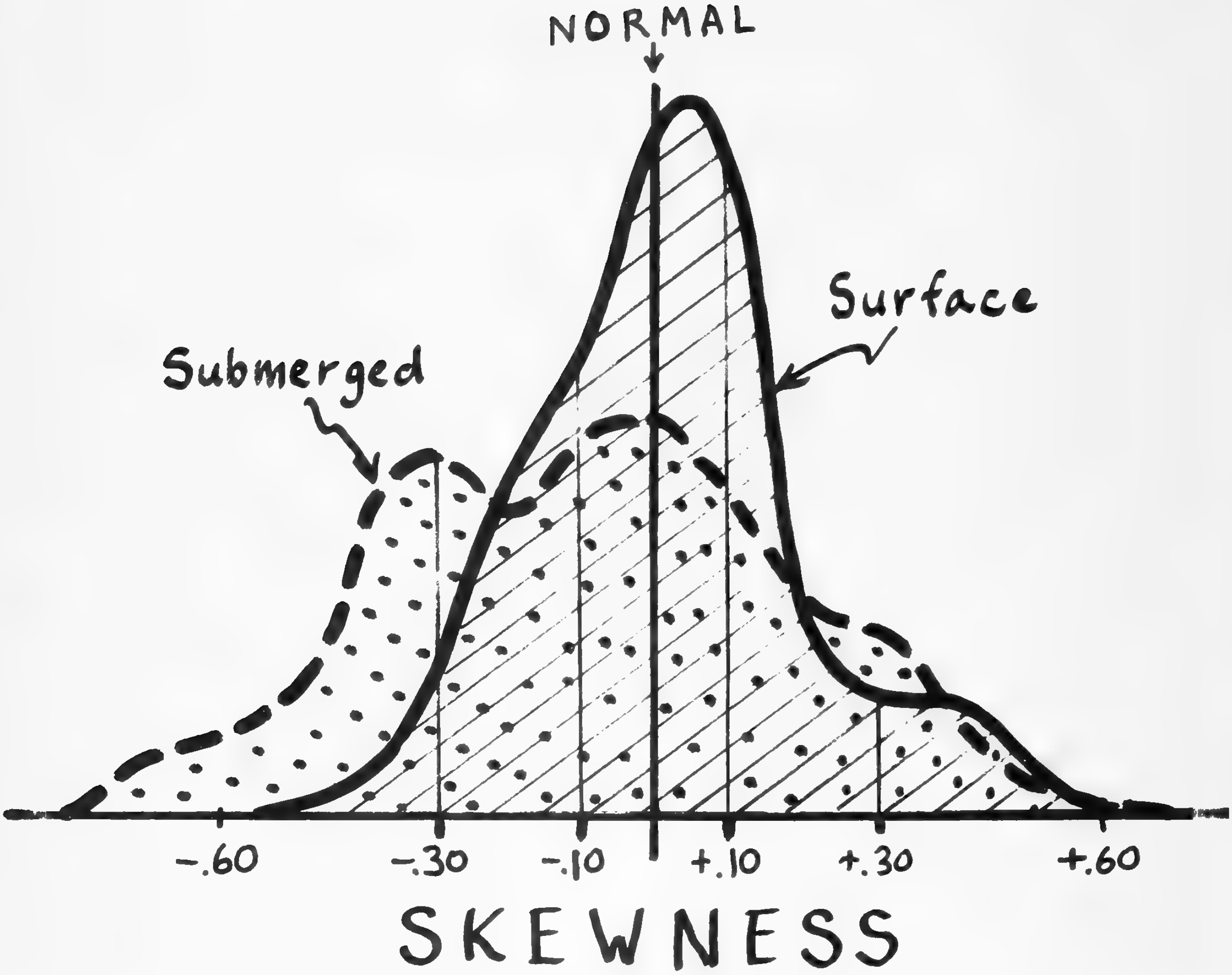


Figure 4. Frequency curve of skewness values for beach surface samples (heavy line), most of which are near-symmetrical; and submerged samples (dashed line), which are more negative-skewed.

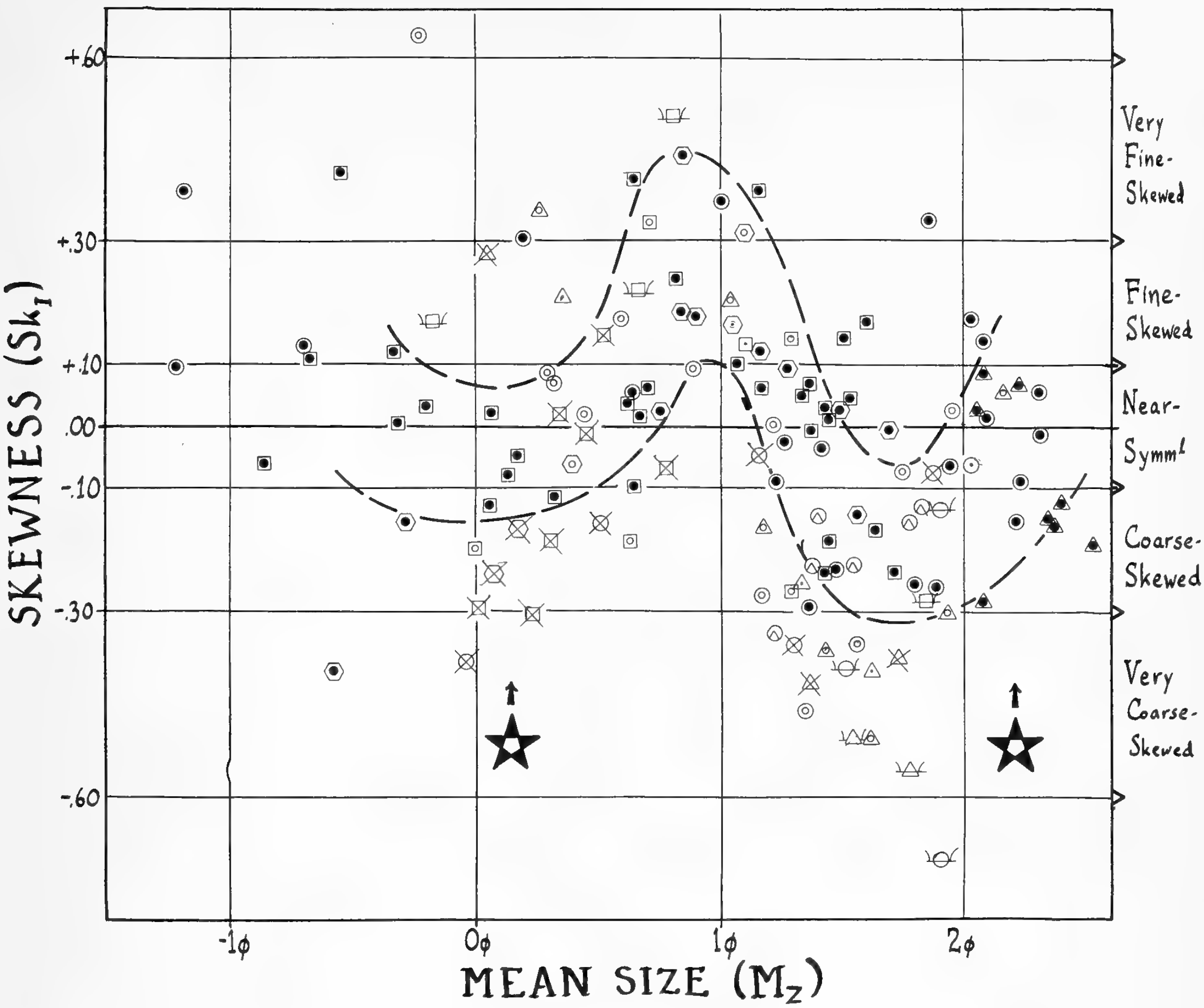
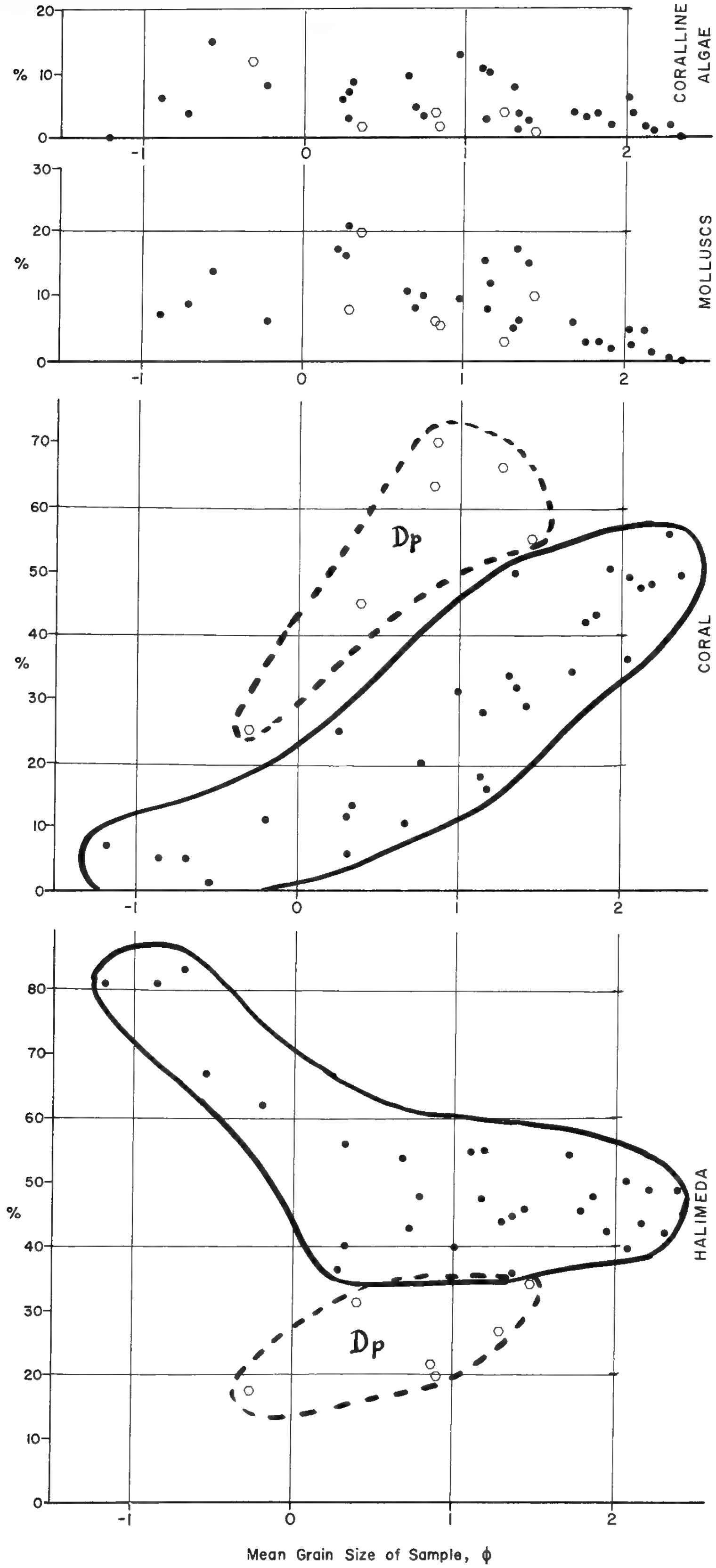


Figure 5. Mean (M_z) vs Skewness (Sk_I). Beach surface samples show a sinusoidal trend, with most nearly symmetrical samples having mean sizes of about 2-2.5ø and 0-0.5ø (Stars). Submerged samples tend to be much more non-normal and are dominantly negatively-skewed. Legend as in Fig. 2.

Figure 6. Constituent composition, plotted as a function of the mean grain size of the total sample. For five of the islands (Solid circles), fine sands consist of subequal *Halimeda* and coral, while coarse sands are largely *Halimeda*. Samples from Isla Desaparecida (Dp) (Open circles) contain more coral and less *Halimeda*. Molluscs and coralline algae are minor constituents in all size grades.



CORALLINE ALGAE
MOLLUSCS
CORAL
HALIMEDA
Dp
Dp
%
Mean Grain Size of Sample, ϕ

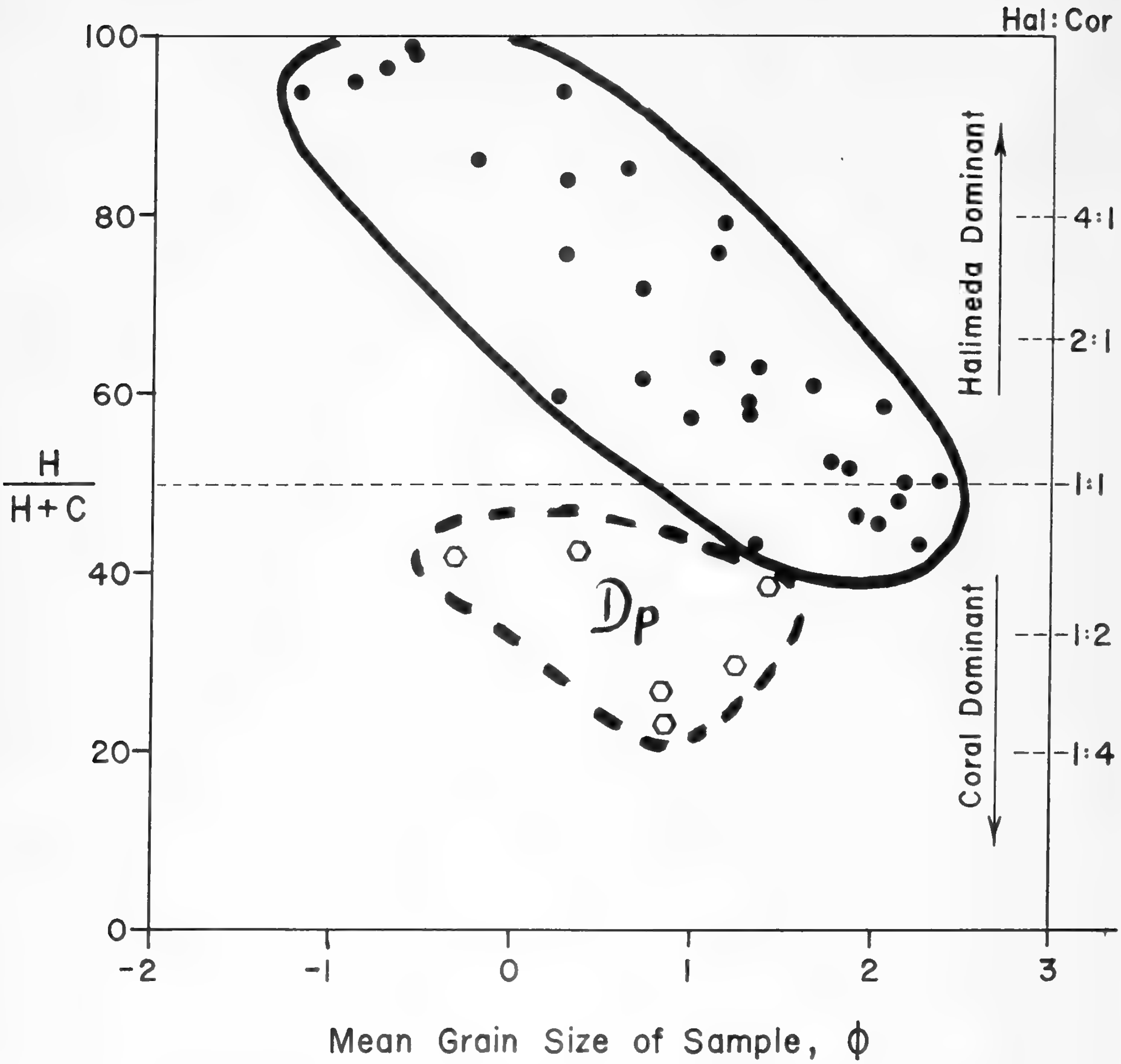


Figure 7. The Halimeda (H) to Coral (C) ratio as a function of mean grain size of the sample. Halimeda predominance increases in coarser sizes. Samples from Isla Desaparecida (Dp) are abnormally low in Halimeda.

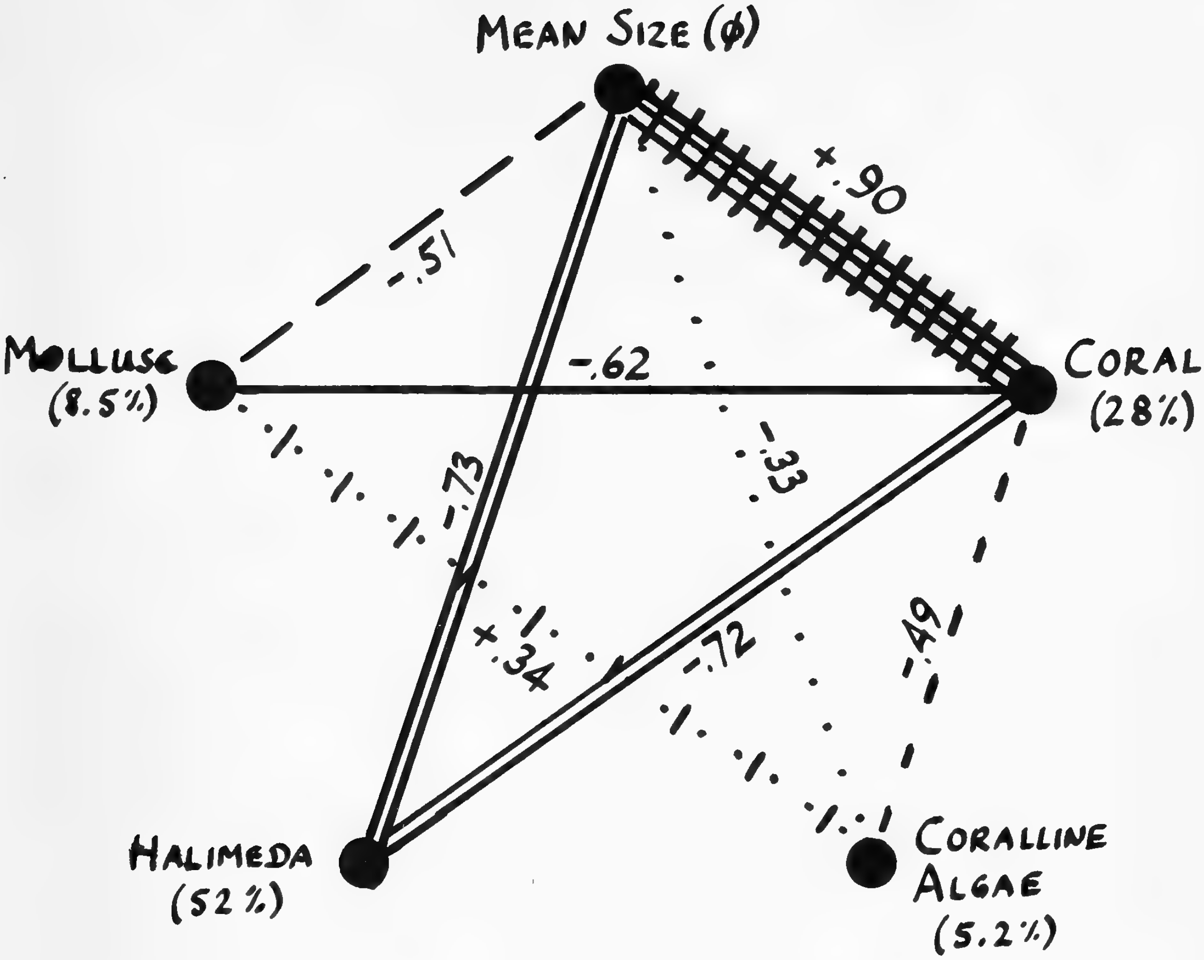


Figure 8. Correlation network diagram based on a matrix of r-values. With the number of samples analyzed, r-values over ± .35 are significant at the 5% level, and over ± .46 at the 1% level. No weaker correlations are shown on this diagram. Positive correlations shown by cross-bars on the connecting lines. Strength of connecting lines indicates numerical value of r. Finer grained sands correlate very strongly with high coral percentage. The finer the sand, the less abundant are <u>Halimeda</u>, Molluscs, and Coralline algae, giving strong (-)r values.

Figure 9. Beach-surface grains of 0 to 0.5ϕ diameter from Isla Pajaros (A) and Isla Desaparecida (B), showing high contrast in rounding, mainly a reflection of rates of supply; Pajaros is near an active reef site, while Desaparecida lies on a barren flat of shifting sand. Fragments are *Halimeda* (chalky white) and coral (grayish).

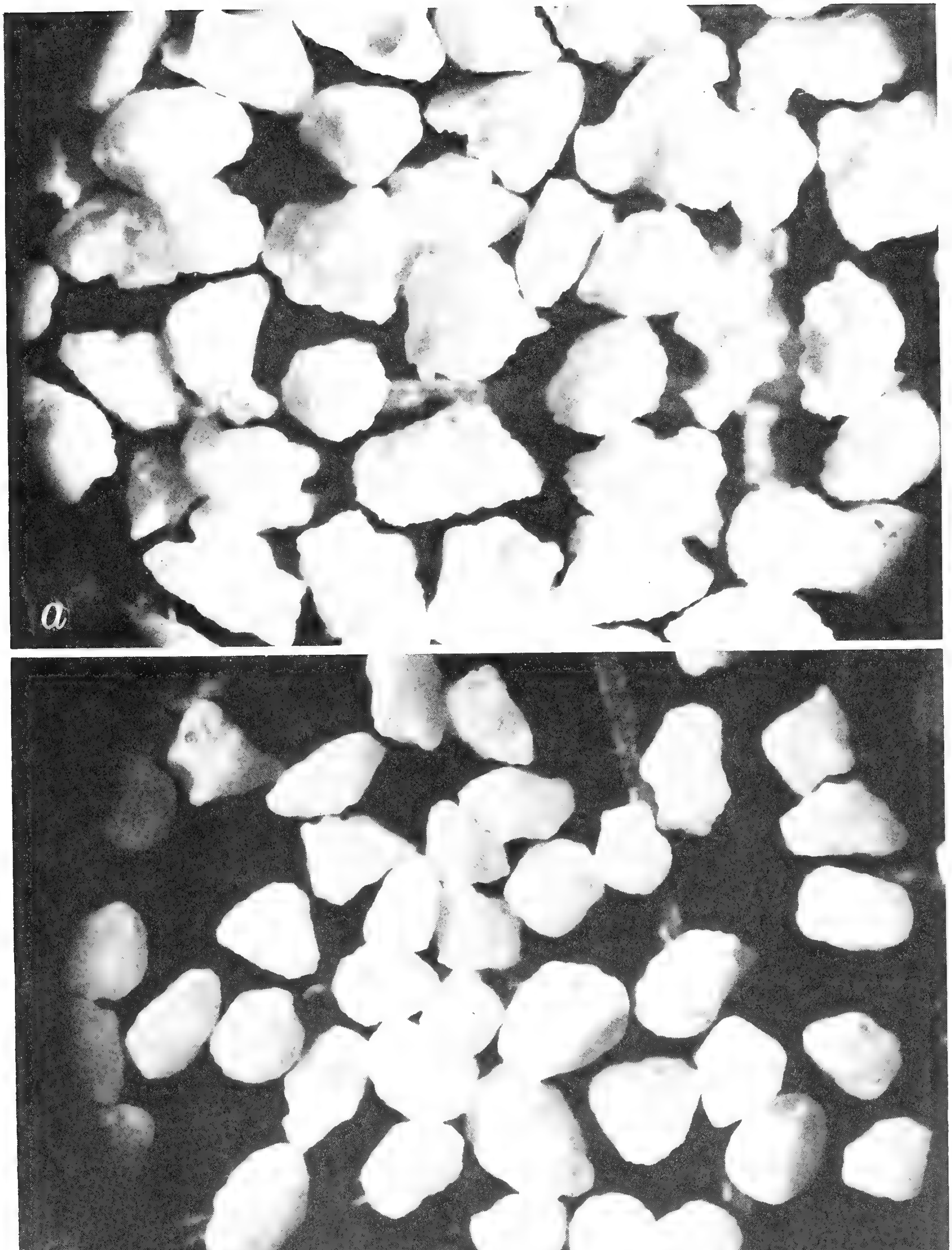
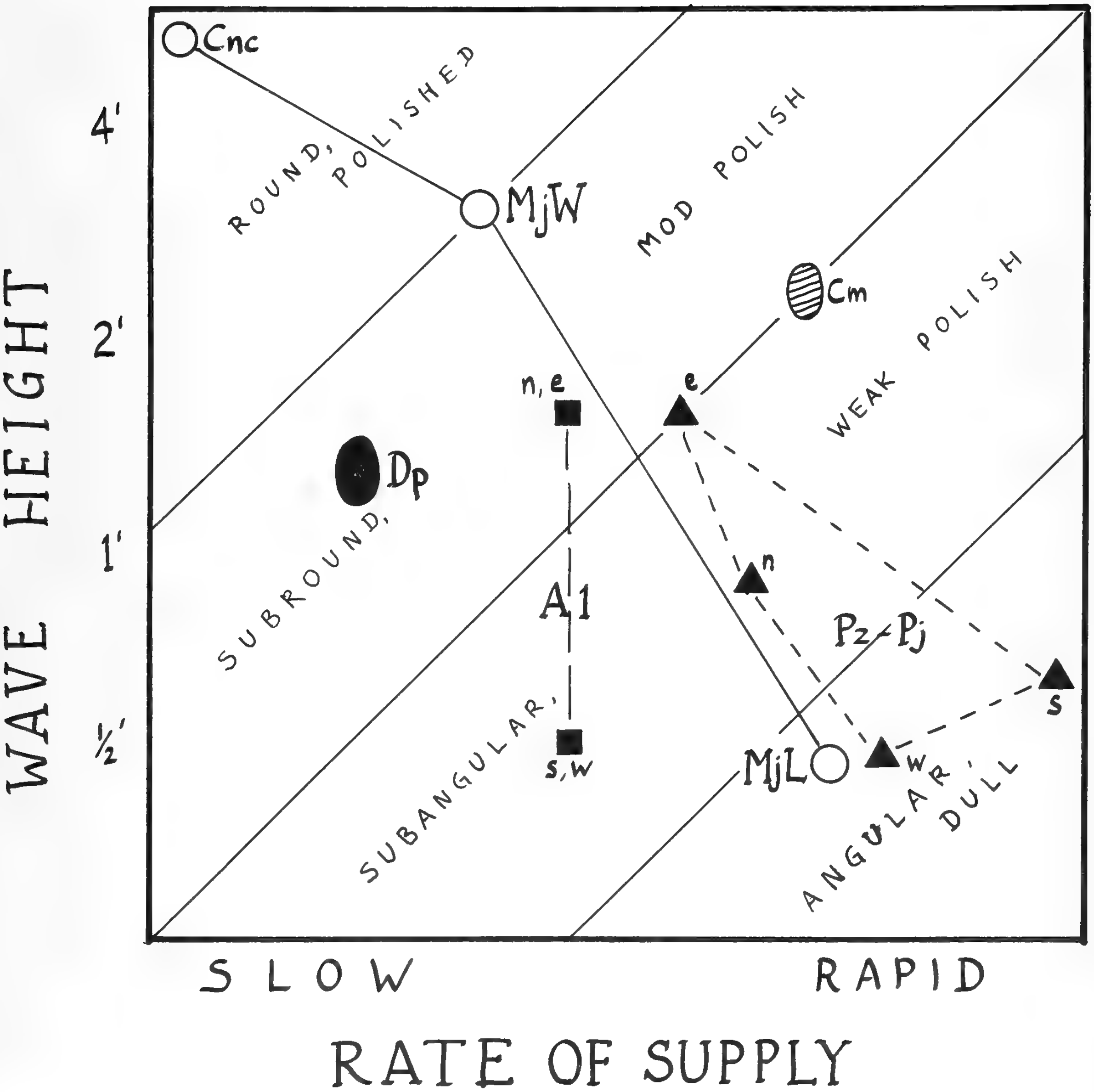


Figure 10. Idealized diagram pointing out the relation between roundness and polish as the result of both rate of supply of organic debris, and wave height (approximate). All data from beach-surface samples.

"Al" represents the most of the cays on Alacrán Reef: East and West Desterrada, Chica, and Desertora, where variation in abrasion is mainly the result of wave energy, being greatest on the north and east coasts. "Dp", Desaparecida, has rounder grains because of a lesser rate of supply. Sands of Perez and Pajaros "Pz-Pj" are generally more angular because of the greater rate of supply (they are nearer the reef edge), but show wide variation from one coast to the other; in both, roundest grains are on the east coast ("e"), because of greatest wave energy combined with locally lower supply rate.

Alacrán data is compared with that from Isla del Carmen (Campeche) and Isla Mujeres (Quintana Roo). Mujeres lee beaches "MjL" are angular, windward beaches "MjW" are much more round, and the beaches of Isla Cancun "Cnc" have extremely well rounded and polished grains; in these areas, and in the Isla Mujeres region, both rate of supply and wave energy seem equally important in controlling roundness.



WAVE HEIGHT
4'
2'
1'
½'
Cnc
MjW
Cm
Dp
n, e
e
n
A1
P2 - Pj
s
s, w
MjL
w
ROUND, POLISHED
MOD POLISH
WEAK POLISH
SUBROUND,
SUBANGULAR,
ANGULAR, DULL
SLOW
RAPID
RATE OF SUPPLY

ATOLL RESEARCH BULLETIN

No. 138

THE VERTEBRATE FAUNA AND THE VEGETATION OF EAST PLANA CAY, BAHAMA ISLANDS

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THE VERTEBRATE FAUNA AND THE VEGETATION OF EAST PLANA CAY, BAHAMA ISLANDS

by Garrett C. Clough[1/] and George Fulk[2/]

GENERAL DESCRIPTION

Three expeditions have been made to East Plana Cay, Bahama Islands, between 1966 and 1968. The primary purpose of these trips was to study the biology of the Bahaman hutia, Geocapromys ingrahami, a hystricomorph rodent which exists only on this island. This paper reports on observations and collections of the lizards, birds and plants and gives a general account of this island together with a brief note on West Plana Cay. Accounts of the ecology and behavior of the rodent population will appear elsewhere (Clough, 1969 and ms. in preparation).

The dates and participants of the three trips were: 1) March 20-24, 1966, G.C. Clough; 2) October 22-28, 1967, G.C. Clough, G. Fulk and Joseph Laterra; 3) March 29-April 4, 1968, G.C. Clough, Robert Howe and John Songdahl.

Acknowledgements

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Characteristics of the Island

East Plana Cay is located at 22° 23' N. Lat. and 73°30' W. Long. The name French Cays is sometimes used for this island and its neighbor, West Plana Cay, about two miles to the west. The Plana Cays lie 82 miles north of Great Inagua, about 26 miles northwest of Mayaguana and 12 miles east of Acklin's Island, near the southeast end of the Bahama Islands.

The island is 1100 acres (465 hectares) in size. It is long and narrow in shape, about 4.75 miles long and 0.5 mile wide at its widest part, and is placed mainly in a southeasterly-northwesterly direction. The southern shore is the leeward shore. It has a gently sloping beach leading to a 2,000 foot-wide shallow coral reef. The northern shore receives the main wave action. On that side the coral reef is narrower and drops off more steeply.

The island is composed of coral rock. In a few places exfoliating reef rock extends into the sea, and in a few places 30 to 40 foot bluffs of eroded coral rock drop steeply to the beach (Plate 1). In most places, however, the island is surrounded by a sand beach which slopes gently from the rocky interior. The topography is generally flat with gentle slopes reaching a maximum of 60 to 80 feet high. Exposed and sharply eroded coral rock forms about half of the surface. In places this is a level pavement with some loose slabs of rock (Plate 2). Cracks, crevices and holes up to three feet in diameter are numerous (Plate 3). On the hillside sites there are loose blocks of rock and shallow accumulations of soil. The western end is composed of sand dunes.

In a few places behind the beach where the rock bluffs are located there are open caves. One of these, near the middle of the south shore, was large enough for us to enter. We could move about 50 feet in from the entrance, through two rooms about 15 feet high and past many small side passages. In a few places in the interior of the island there are round depressions from 10 to 15 feet deep and 20 to 30 feet in diameter. One of these could be seen on the aerial photographs to be filled with water. On the north side of the island, just behind the sand beach crest, the holes and crevices in the rock pavement were filled with clear sea water, which rose and fell with the tide.

During our three visits to the island, which included extensive exploration, we found fresh water only once. That was in a stagnant puddle three inches deep and a few feet across located in a depression in the rock surface.

Climate

The climate in general is warm and dry. The maximum and minimum temperatures we recorded from October 22 to 28, 1967 were 94°F (34.4°C)

and 71°F (21°C). The nearest station for which we found any meteorological records was Great Inagua. Howard and Dunbar (1964) examined rainfall records kept by the salt company there and found the average annual rainfall was 25 to 35 inches (635 to 890 mm). They state that "there is no regular wet or dry season although somewhat more rain is recorded for September, October and November". During our three visits there were only a few passing traces of precipitation.

Official weather stations are located at Nassau, 295 miles to the northwest and at Grand Turk Island, 170 miles to the southeast. Data from Walter and Lieth (1967) for these stations are: Nassau, mean annual temperature of 25°C (77°F) over 47 years and mean annual sum of precipitation of 1181 mm (47 inches) with a wet season from May through October. Grand Turk Island, mean annual temperature of 26.3°C (79.3°F) over 27 years and mean annual sum of precipitation of 750 mm (29.5 inches) with a period of high rainfall in October and November.

LIZARDS

Three lizard species were collected. These were identified by Dr. Ernst Williams and Mr. B. Shreve of the Museum of Comparative Zoology, Harvard University. The name and catalogue numbers of specimens are listed below.

Leiocephalus greenwayi Barbour & Shreve
MCZ 111416-19

Anolis carolinensis brunneus Cope
MCZ 111420

Sphaerodactylus corticola aporrox Schwartz
MCZ 111421

The *Leiocephalus*, round-tailed lizard, was very abundant in both the rocky and sandy areas. They were diurnal in activity. The *Anolis* were seen only occasionally in the daytime. They inhabited the palm trees at the west end of the island. One *Sphaerodactylus*, gecko, was seen. It was collected at night from soil in open shrub vegetation.

BIRDS

Observations of birds were made during October 1967 by G. Fulk and during March-April 1968 by G. C. Clough. An annotated list containing 37 species follows.

Procellariidae

<u>Puffinus lherminieri</u>, Audubon's Shearwater
March. Two or three adults seen each night sitting at cave entrances or flying near caves. Birds heard calling in flight over land and water. One adult found 50 feet inside large cave in daytime.

Phaethontidae

<u>Phaethon lepturus</u>, White-tailed Tropicbird
October. A single individual seen once.
March. Groups of 10-15 seen every day flying over reefs.

Sulidae

<u>Sula leucogaster</u>, Brown Booby
March. One immature bird flying by the island, one-quarter mile out from beach.

Ardeidae

<u>Ardea herodias</u>, Great Blue Heron
October. Two birds seen together once.

<u>Butorides virescens</u>, Green Heron
March. One seen perched on dead buttonwood tree.

<u>Dichromanassa rufescens</u>, Reddish Egret
March. Two birds together at brackish pond at east end.

<u>Nyctanassa violacea</u>, Yellow-crowned Night Heron
October. One individual seen at night in shrubs along shore.

Pandionidae

<u>Pandion haliaetus</u>, Osprey
October. Adult ospreys seen near three nests, a fourth nest was abandoned. One nest on rocky bluff, another in top of a buttonwood tree, another at top of old steel tower.
March. Ospreys seen daily. Five birds seen together in vicinity of nest at northwest end.

Falconidae

<u>Falco</u> sp.
October. One large falcon seen flying over island.
One small falcon seen three times.

Rallidae

<u>Rallus longirostris</u>, Clapper Rail

March. One individual seen and captured at night on north beach terrace. One seen at dusk walking through shrub thicket.

Haematopodidae

<u>Haematopus ostralegus</u>, Oystercatcher

October. Single individuals seen twice in mixed flocks of shorebirds.

March. Two pairs seen along beach.

Charadriidae

<u>Charadrius wilsonia</u>, Wilson's or Thick-billed Plover

March. One seen.

<u>Charadrius hiaticula</u>, Northern Ring-billed Plover

October. Five seen together with Oystercatcher and Black-bellied Plovers.

<u>Squatarola squatarola</u>, Black-bellied Plover

October. Five birds seen in one flock.

Scolopacidae

<u>Arenaria interpres</u>, Ruddy Turnstone

October. Seen daily in small flocks of three to six.

<u>Crocethia alba</u>, Sanderling

October. Seen in small flocks of two to four.

Columbidae

<u>Columbigallina passerina</u>, Ground Dove

October. Individuals or pairs seen frequently along beach terrace and in open rocky areas.

March. Individuals, pairs or groups of four seen along beach terrace.

Cuculidae

<u>Coccyzus americanus</u>, Yellow-billed Cuckoo

October. One seen in shrub thicket.

Trochilidae

Unidentified Hummingbirds

October. One seen daily in shrub thicket. One had green head and back, white belly and throat, rusty red sides beneath wings,

straight bill, no crest. Another had brilliant red chin and throat.
March. One hummingbird seen at brackish pond.

Alcedinidae

Ceryle alcyon, Belted Kingfisher
October. Single bird seen twice along beach.
March. One seen perched on tree at beach edge.

Picidae

Sphyrapicus varius, Yellow-bellied Sapsucker
March. One seen in buttonwood tree, was chased by Mockingbird.

Mimidae

Mimus gundlachii, Bahama Mockingbird
October. Three single birds seen in low shrub thickets in different parts of the island.
March. A few males singing from elevated perches in shrub thickets.

Dumetella carolinensis, Catbird
October. A few birds seen in shrubs and buttonwood trees.

Coerebidae

Coereba flaveola, Bananaquit
October. Three birds seen in buttonwood tree.
March. Three different males singing in or near buttonwood trees.

Parulidae

Parula americana, Parula Warbler
October. Single birds seen several times in buttonwood trees.

Dendroica petechia, Yellow Warbler
October. Single males seen near trees.
March. One male seen foraging in litter below buttonwood tree.

Dendroica magnolia, Magnolia Warbler
October. Seen twice, feeding in low shrubs.

Dendroica caerulescens, Black-throated Blue Warbler
October. Single birds seen twice in buttonwood tree.

Dendroica coronata, Myrtle Warbler
October. Seen daily, in groups of up to five birds, foraging in Ambrosia on beach terrace and in low shrubs. Attracted to fresh water at our camp.

Dendroica striata, Blackpoll Warbler
October. One seen foraging in shrub thicket.

Dendroica palmarum, Palm Warbler
October. A few seen in Ambrosia on beach terrace.
March. A few groups of six to eight birds seen along beach and interior.

Seiurus aurocapillus, Ovenbird
October. Single birds seen twice.

Wilsonia citrina, Hooded Warbler
October. One bird seen under buttonwood tree. Very tame.

Setophaga ruticilla, Redstart
October. Seen four times in buttonwood trees and shrubs.

Fringillidae

Tiaris bicolor, Black-faced Grassquit
October. One pair seen.
March. A few males singing from perches or on the ground.

Ammodramus savannarum, Grasshopper Sparrow
October. Seen once along beach.

VEGETATION

Plant Communities

Most of the island is covered with a continuous shrub layer of an even height of three to four feet. The greatest variation in the vegetation is found along the beach with its zones of changing slope and moisture characteristics. Eight plant communities could be recognized as containing one or more dominant species growing on sites distinguishable by soil type and topography.

1. Beach slope
This is the outer zone of vegetation on the sloping sand beach. It consists of Tournefortia gnaphalodes, growing as widely spaced bushes about two to four feet high (Plate 4).

2. Beach crest
This community grows on the top of the beach slope. It occurs in only a few areas and then is a few feet wide. It consists of sparse growths of Cakile lanceolata and Sophora tomentosa.

3. Sand terrace

This is the flat sandy area located behind the beach crest. It is up to 40 feet wide in some places and absent in other places. It contains *Ambrosia hispida* primarily with *Capraria biflora* in a few places (Plates 4 and 5).

4. Shrub thicket on rock

On exposed rock *Strumpfia maritima* grows in pure stands. This is mainly on the higher ground or steep slopes where all soil is absent.

5. Shrub thicket on sand soil

Where there is soil, mixed communities of shrubs are found. These consist primarily of four species, *Phyllanthus epiphyllanthus*, *Forestiera segregata*, *Croton lucidus* and *Croton linearis*. This community blends into the *Strumpfia* community where the substrate is part sand and part rock (Plate 6).

Croton thickets were classified by Beard (1949) as a subclimax community of the Windward and Leeward Islands of the southeast Caribbean region. These thickets, composed of various species of *Croton*, Beard said were "the most impoverished" of any of the plant communities, found on only the "driest, poorest and most degraded sites".

6. Tree grove

In a few places small clumps of buttonwood trees, *Conocarpus erectus* grew. These are found at the edge of the Sand terrace or Brackish water border communities and in the island interior around exposed rock pavements (Plate 2). The trees vary from a few feet to about 15 feet high. A few taller dead tree trunks stood along the south shore at the beach crest.

7. Palm grove

One grove of silver thatch palm trees grows near the west end of the island on sandy soil. These are about 20 to 30 feet tall (Plate 7).

8. Brackish water border

At the edges of the brackish ponds at the west end there are stands of saltwort, *Batis maritima*.

Brief descriptions of East Plana Cay's vegetation made by D.P. Ingraham in 1891 (Allen 1891) and by Rabb and Hayden (1957) during their visit in 1953 are nearly identical with those made in 1966 to 1968. As the only difference Ingraham mentions the presence of a few paw-paw trees, *Carica*, and says the hutia "seemed very fond of the fruit of the paw-paw, and even of the body of the tree itself, as I have seen the trunk of this tree, nearly as large as my body, eaten so nearly off that they could not sustain their own weight." We found four paw-paw trees, all of which were about four to six inches in diameter. Perhaps this species has been nearly eliminated from the island by the hutia

population. It was impossible to discover what other effects the very high rodent population has exerted on the vegetation over a long period of time.

Vascular Flora

Plants were collected on the second and third trips by G. C. Clough. The identifications were made by Dr. F. R. Fosberg and Dr. M.-H. Sachet of the Smithsonian Institution. Dr. R. Hauke, University of Rhode Island, assisted in the determinations. One set of specimens is on file with the Smithsonian and another set with the Fairchild Tropical Garden, Miami, Florida.

In addition to the 29 species listed below there were at least two grass species which were not collected or identified. One grass species was observed as a dense patch about 12 feet in diameter in the interior on sand soil and the other grass grew in a few places in the Beach crest community. The six species of plants known to be eaten by the hutias are indicated below. Hutia food habits were determined by observations of animal activity, examination of plants for signs of grazing and browsing, and food preference tests of captive animals performed on the island.

Palmae

Coccothrinax argentata (Jacq.) Bailey

Palm called the silver thatch palm by Rabb and Hayden (1957). These were located near the west end, in the same place where they grew in 1891 (identified from photo by R. W. Read).

Amaryllidaceae

Hymenocallis littoralis (Jacq.) Salisb.

A few clumps growing in Sand terrace community.

Ulmaceae

Trema lamarckiana (R. and S.) Bl.

Two to four feet high, flowering in March. Common in Shrub thickets on sand soil.

Moraceae

Ficus aurea Nutt.

Rare, interior of island. Fruit in October.

Batidaceae

Batis maritima L.

At edges of brackish ponds growing in mud.

Portulacaceae

<u>Portulaca phaeosperma</u> Urb.
One inch high, on exposed, bare rocks.

Cruciferae

<u>Cakile lanceolata</u> (Willd.) Schulz
In Beach crest community. Flowering in October and March.

Leguminosae

<u>Sophora tomentosa</u> L.
In Beach crest community.

Simarubaceae

<u>Suriana maritima</u> L.
Rare, on Beach crest. Prostrate form, two to three feet high, flowering in March.

Euphorbiaceae

<u>Phyllanthus epiphyllanthus</u> L.
Common, two to five feet tall. <u>Hutia food</u>.

<u>Croton linearis</u> Jacq.
Abundant, flowering in October and March.

<u>Croton lucidus</u> L.
Abundant, flowering in March. <u>Hutia food</u>, low preference.

<u>Euphorbia mesembryanthemifolia</u> Jacq.
In Sand terrace community.

Caricaceae

<u>Carica papaya</u> L.
Rare, a few individuals on the island. Ten to twelve feet high.

Cactaceae

<u>Cephalocereus</u> sp.
Uncommon, four feet tall.

<u>Melocactus intortus</u> (Mill.) Urb.
Uncommon, isolated individuals on rocky substrate, in bloom.

<u>Opuntia</u> sp.
Uncommon, on Sand terrace.

Combretaceae

Conocarpus erectus L.
Common, up to 15 feet high, taller dead trunks. Hutia food.

Oleaceae

Forestiera segregata (Jacq.) Krug and Urb.
Abundant. Heavy fruit crop in March 1968. Hutia food.

Asclepiadaceae

Metastelma sp.
A vine, growing over Opuntia. Flowering in October.

Convolvulaceae

Evolvulus squamosus Britton
Uncommon, on sand soil of Shrub thicket community.

Ipomoea repanda Jacq.
Vine creeping on ground. Flowers in October.

Boraginaceae

Tournefortia gnaphalodes R. Br.
Common on Beach slope. Flowering in March. Hutia food, low preference.

Verbenaceae

Lantana involucrata L.
Uncommon, shrub one to three feet tall. A few on Sand terrace. Flowering in March.

Labiatae

Salvia serotina L.
Uncommon. In openings of Shrub thickets on sandy soil. Six to ten inches tall.

Scrophulariaceae

Capraria biflora L.
Uncommon. In Sand terrace community. A few flowers left in March, most in seed then. Six to ten inches tall.

Rubiaceae

Antirrhoea myrtifolia (Griseb.) Urb.
Uncommon. In Sand terrace community. Isolated plants six inches tall. Flowering in October and March.

Strumpfia maritima Jacq.
Abundant. Flowering in October. Hutia food, top preference.

Compositae

Ambrosia hispida Pursh
Abundant in Sand terrace community.

NOTES ON WEST PLANA CAY

In March 1966 G. C. Clough visited West Plana Cay, going ashore at three different points on the west and northwest sides. A total of three hours were spent on shore observation tours. In 1967 and 1968 aerial observations were made by expedition members as they passed over the island in a low-flying airplane.

West Plana Cay is quite different from its neighbor. In shape it is more nearly round; in size it is nearly the same. There appears to be very little exposed coral rock on the island and much more soil. The vegetation is thicker and higher in many places. Grasses are common. At the northwest point the remains of an old village made of stone huts are found. Nearby is a new village of wood and thatch homes which are used temporarily every summer by residents of Acklin's and Crooked Islands. Coconut palm trees and garden plots were present around the old and new villages. Two shallow wells which contained some fresh water had been dug near the new village. One object which might possibly have been a very old fecal pellet of a hutia was found along the beach. Otherwise, absolutely no signs of hutias were found on West Plana Cay.

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Plate 1. East Plana Cay. Bluff on northern side with osprey nest on top of rock at left.

Plate 2. East Plana Cay. Flat rock pavement with broken slabs and crevices. Low Conocarpus trees and Phyllanthus shrubs.

Plate 3. East Plana Cay. Eroded hole in rocky interior which served as diurnal shelter for the rodents, Geocapromys ingrahami. Phyllanthus shrubs.

Plate 4. East Plana Cay. South shore with the Beach slope community of Tournefortia in center. The Sand terrace community with Ambrosia begins at the right. One clump of Conocarpus in center.

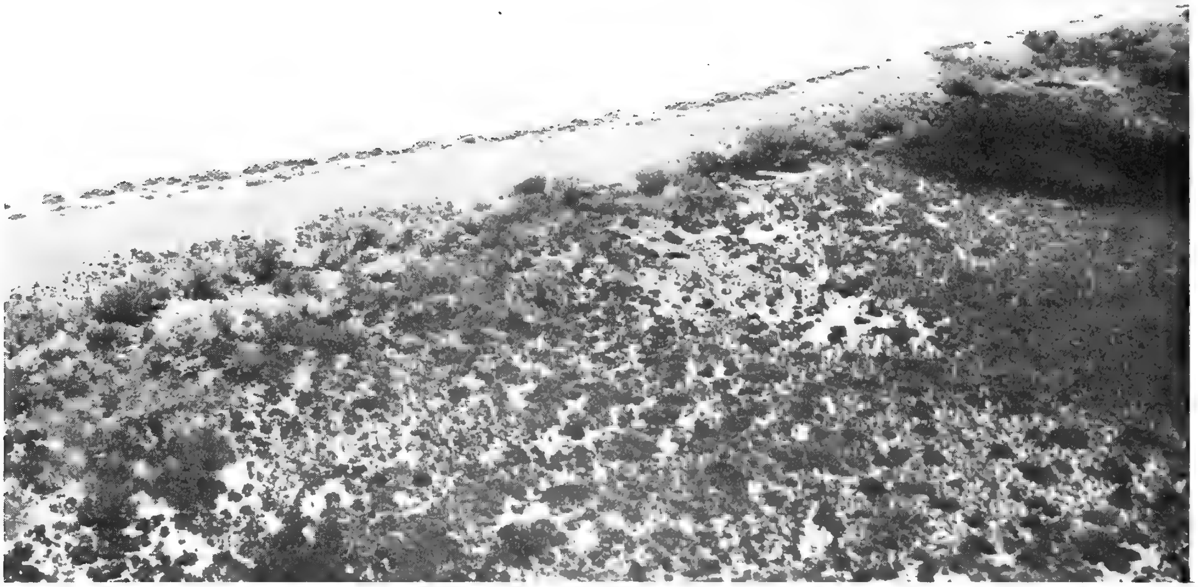

Plate 5. East Plana Cay. Aerial photo of south shore. Beginning from the shore three plant communities are visible: Beach slope, Sand terrace and Shrub thicket on sand soil. The Beach crest community is too narrow to be visible.

Plate 6. East Plana Cay. Interior view of Shrub thicket on sand soil which contains the four main species. Strumpfia enters in the background.

Plate 7. East Plana Cay, near western tip. The grove of silver thatch palms.

ATOLL RESEARCH BULLETIN

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THE ISLAND OF ANEGADA AND ITS FLORA

by W. G. D'Arcy

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THE ISLAND OF ANEGADA AND ITS FLORA

by W. G. D'Arcy

The island of Anegada in the British Virgin Islands is of interest because of its isolated location in relation to the Antillean island arc, its unusual topography amongst the Virgin Islands, and also the fact that it has received very little scientific attention. It now seems destined to join the list of islands which have succumbed to modern "development". This checklist combines past published reports with the writer's own collections and attempts to correct the nomenclature formerly applied to this flora.

THE ISLAND

Anegada is the northeasternmost of the British Virgin Islands and of the entire West Indian arc for that matter, vying with the rocky lighthouse, Sombrero, well to the southeast, as the closest Antillean approach to Europe. Its geographic coordinates are 18°45'N and 64°20'W, and it encompasses 14.987 square miles (Klumb and Robbins 1960) or about 33 square km. In shape it is a rather lumpy crescent with its long axis running approximately west by north and east by south. The nearest land, Virgin Gorda, some thirteen miles (ca 22 km) to the south and slightly west, is a prominent feature on the horizon (Fig. 1), as is the mass of the other Virgins--Tortola, Camanoe and Jost Van Dyke--further to the southwest. To the north and east there is no land for a long way.

Unlike the other Virgin Islands which display rather sharp relief, with an elevation of 1,780 feet (450 m) on Tortola and elevations of over 1,000 feet (300 m) on several other islands, Anegada is flat. On approaching it by small boat from the west, one sees the four or seven stunted coconut trees long before actual land can be perceived. Schomburgk (1832) mentions a height of 60 feet at the east end of the island, and Britton (1916) suggests a height of 30 feet. The greatest elevation today would seem to be less than half that, and much of the island must be less than ten feet above sea level.

The island surface is of an almost white coquina limestone which over much of the area has a flat, planed appearance as if some prehistoric workers had levelled it to make roads. Even in sandy places, there is considerable scree or broken rock lying about.

Schomburgk mentions taking "gravel" and not shells at depths of over thirty feet (9 m) from the surface, and it would be interesting to know what sort of gravel this is.

A considerable portion of the surface of Anegada is occupied by salt or brackish ponds, which in the west sometimes flood large areas. In places, there is a depth of sand which has been suitable for growing cotton, tomatoes and provision crops at various times in the past. In other places the surface is stony with little soil or sand cover. Here and there, but especially at the middle of the island nearer to the Atlantic coast, are a number of slobs, or funnel-like natural wells of fresh or almost fresh water. There is apparently one or more large aquifers beneath the island which have only minor connections with the sea. Although Schomburgk reports fluctuations in the water table, ground water is probably available to shrubs and trees at most times.

The original vegetation is difficult to envision, but it must have been much more developed than it is now. Schomburgk mentions clearing of the underwood, and since then there has been charcoal cutting and pasturing of goats and cattle. Near The Settlement, which is in the eastern portion of the island, there is severe overgrazing so that with the exception of one or two carefully kept yards, the landscape has the appearance of an unwholesome wasteland. Other parts of the eastern portion of the island consists of an open woodland with well dispersed trees of considerable basal girth but all evenly trimmed at the top by the winds so that only the few coconut trees already mentioned manage to surpass a height of about 15 feet. Along the south coast which is somewhat sheltered from currents and winds there is mangrove vegetation.

The 1960 population of Anegada was 300 (Klumb & Robbins 1960), but was declining until in 1967 it was only about 100 inhabitants. Most of them lived in The Settlement, getting their livings by fishing or remittances from outside. According to local legend, The Settlement was situated where it is, miles from any deep-water landing, so that there could be time for warning to hide the women when buccaneers landed. A more likely reason is the attempt to locate away from occasional flooding to the west near where the deep water is to be found. Another legend, perhaps of some charm to outsiders but not to Anegadians, is that Anegada will one day sink beneath the sea. Proof of this will be unfortunate for vegetation and residents alike.

Impact of the outside world has been gaining force. Charcoaling and grazing have traditionally taken their toll of the vegetation, and materials for the construction of fish-pots before wire came into general use were supplied by local species. In the 1950's an American missile tracking station was operated on Anegada. At about the same time, Mr. Norman Fowler, now a Road Town personality, brought modern concepts to bear on tomato farming and shark fishing; and for the past ten or fifteen years there have been numerous, well-equipped visits by

Puerto Rican duck hunters. With increased awareness of the island by outsiders and the declining population of Anegadians, it is not surprising that the island is now being developed. Recent issues of the Island Sun (Road Town) describe plans for large scale subdivision including an international airport. The present entrepreneurs seem to be well financed and the bulldozers are already at work.

Botanical Collections

Anegada was visited by N. L. Britton, Director of the New York Botanical Garden, and W. C. Fishlock, Curator of the Botanical Station at Road Town, Tortola, on February 19-20, 1913, and the botanical collections were described by Britton (1916). Courtesy of the Government Medical Officers, I was able to visit the island in 1959 and again in 1967, when I was able to take some botanical specimens. Time on these visits was limited to that of the two or three hour clinic conducted by the Medical Officer, but it did permit a walk from The Settlement to Loblolly Bay on the Atlantic side. Besides my account here and that by Britton, I know of no other published botanical records for the island, but Dr. R. A. Howard, The Arnold Arboretum, Jamaica Plain, Mass., Mr. Roy Woodbury, Agricultural Experiment Station, Rio Piedras, Puerto Rico, and Dr. Elbert L. Little, Jr., United States Forest Service, Washington, D. C., have each mentioned to me in the past that they know of other small collections now in different herbaria.

Acknowledgements

Mr. Henry Milstrey and Mr. Robert Nevin of Road Town provided assistance, and of course the Government Medical Officers, Mr. Parker and Dr. Tattersall, provided transportation. Mr. Parker, an outstanding London surgeon, was of more than passing assistance at a later date. Mr. Roy Woodbury and Dr. R. A. Howard were kind enough to help with identification of specimens.

THE FLORA

The known flora of Anegada comprises 139 species of angiosperms, two mosses, one charophyte and eight lichens. The flora consists of species capable of growing on limestone; in various, but always some, element of salt spray; and under xeric stress from oceanic winds passing over a small, hot land mass. Britton considered the island to have one endemic genus and five endemic species, a considerable number for an island of this size in the West Indies. The principal floristic relations are with the other Virgins and with Puerto Rico, but the relationships with the Bahamas and Hispaniola are also of interest. Much of the flora is of widespread West Indian species.

The endemic genus Fishlockia consists of one species, F. anegadensis, which was first described as an Acacia. It is a plentiful tree, with very dark green foliage and large fascicles of strong, acicular spines to 8 cm long on the trunk and main branches. In foliage it closely resembles a number of West Indian species of Pithecellobium, e.g., P. unguis-cati and P. kewensis, and to some extent the Mexican P. calostachys. The foliage does not resemble that of Acacia. An examination of all acacias at the Missouri Botanical Garden, which included a good representation of African and other Old World species, disclosed no species which approached Fishlockia even remotely. As for the spines on the trunk, such spines are recorded on Acacia acuifera, a species endemic to the Bahamas, but one which has multi-pinnate leaves, as is usual for West Indian acacias. The flowers closely resemble those of the pithecellobiums mentioned but have the Acacia character of free stamens. Britton & Rose (1928) may have had the same temptation as I, to transfer the species to Pithecellobium, but chose to consider it a distinct genus. Monographic work with a good circumscription of Pithecellobium would be useful in assigning this taxon. In any event, it is a highly distinctive entity with its closest relative apparently in the nearby Bahamas.

The other endemics are not so dramatic. Chamaesyce anegadensis may be a synonym of C. turpinii (see Burch 1966, p. 96). C. turpinii also occurs on Hispaniola, and I have collected it at Salinas de Ensenada on the south coast of Puerto Rico. It is a succulent little species that hides in holes in the limestone at the edge of the sea. The Astephanus mentioned by Britton (1916) was later described by him as a Metastelma and transferred to Cynanchum in 1963. This is a large genus which includes many Antillean species of rather inconspicuous distinction. Britton referred to a still undescribed species of Sabal which he thought was new, but he was unwilling to describe it because it lacked flowers and fruit. The fifth endemic was a lichen, Arthonia anegadensis, growing on bark of Pisonia subcordata. Thus, the endemism of the island reduces to one endemic genus and two described species of higher plants, plus one species of lichen.

The list of species includes few exotics. Dactyloctenium aegyptium, Cocos nucifera, Aloe barbadensis and Nerium oleander were introduced by post-Columbian man, and it is known that Lycopersicon esculentum and Gossypium spp. have been cultivated in the past. Any non goat-proof introductions were not likely to persist.

A good part of the Anegada flora is a littoral element widespread throughout the Caribbean area, and about a dozen species are common to the coasts of the New World and Africa (Guppy 1917). The closest relationship of the flora is with Puerto Rico and the other Virgin Islands. Some twenty non-endemic species in the Anegada list have not been reported for the other Virgins, and only seventeen are not found on the island of Puerto Rico. Species which do not occur on the other Virgins or on Puerto Rico have ranges north to the Bahamas or south to

the Leeward Islands, and a few reach others of the Greater Antilles. Fimbristylis inaguensis, Thrinax morrisii, Salicornia perennis, Malpighia linearis, M. infestissima, Centaurium brittonii, Jacquemontia cayensis, Evolvulus squamosus, Cordia bahamensis, Lycium tweedianum all miss Puerto Rico. They are better known from the flat islands to the outside of the island arc.

A striking feature of Anegada's floristic relationship is the affinity with Hispaniola. Over 100 species of the Anegada flora occur on Hispaniola, and of these seventy occur in Barahona Province, Dominican Republic. Several species have been reported for Hispaniola in Barahona or Azua provinces only, e.g., Piriqueta diffusa, Pilea tenerrima, and Phyllanthus polycladus (Moscoso 1943), but further collecting may show wider distributions on this island.

Anegada is isolated not only in terms of simple geography but also in terms of the vectors which might enrich the flora. Hurricanes are few and generally come from the south, perhaps never from the west or north. The prevailing winds are from the east and seldom pass over other land before reaching this island. Ocean currents come steadily from the southeast or east, the Antillean Stream mentioned by Guppy (1917). Winds and currents, when they do pass over land first, are associated with Sombrero, Anguilla or Barbuda, similar islands of the outer arc, but this is not usually the case, for the winds and currents from these islands most commonly pass more directly to the west. The continuous winds over Anegada must discourage most birds. Bond (1961) shows that the outer islands are on the migration routes of birds passing through the Bahamas on their way to the Leeward Islands to southward.

Ocean currents moving to the west may do so in two directions from Anegada. Schomburgk describes the drift to the northwest as steady at about one knot, and this current moves in the direction of Turks and Caicos and the Bahamas, but must sometimes shift southward and be deflected to the north by the bulge in Hispaniola near Puerto Plata, Dominican Republic. Ocean currents may also take a more southerly course to the west from Anegada, either through the Sir Francis Drake Channel, where it causes a substantial rip current at the west end of Tortola, or by way of the much larger Anegada Passage between Anegada and Anguilla. These two currents unite south of St. Thomas and continue westward along the south coast of Puerto Rico and Hispaniola until directed sharply southward into the Caribbean by Barahona Province.

The vectors relating to floristic interchange with Anegada make it feasible for propagules to move from east to west or northwest, but with the exception of bird movements from the Bahamas southeastward to Anegada, movements to the east are less likely, especially over the distances considered. The Mona Passage between Puerto Rico and Hispaniola is over fifty miles across, and the distance from Barahona to Anegada is over five hundred miles. The grand circular movements of currents to shores of Anegada via the coasts of Central America and the coasts of Europe

and Africa would disperse only those plants adapted to long time periods on the water.

As pointed out by Little (1969), as recently as 11,000 years ago Northern Hemisphere glaciations caused a lowering of sea level sufficient to join all of the Virgins except St. Croix with Puerto Rico. A lowering of about 120 feet would be sufficient to achieve this, while it is estimated (Clark & Stearn 1960) that the actual lowering may have reached 350 feet. A continuous Puerto Rico-Virgin Island land mass must have persisted for several thousand years at its latest occurrence (Wisconsin glaciation), and this no doubt allowed many plants to move between the now recognized islands by overland migration. As seas rose, species which were not adapted to dispersal over water became isolated on insular land areas. Those in the eastern part of the former area gradually ceased to receive genes from the western part, and with release from the larger gene pool, speciation was free to favor plants adapted to the special environments at the eastern edge. Plants in the west would for a long time, and do to some extent still, receive genes from the eastern populations in the form of pollen grains carried by wind-blown insects and off-course birds and as seeds and other propagules carried by winds and currents from east to west. This one-way movement of the vectors from the easternmost islands, of which Anegada is the extreme example, is clearly important in accounting for the endemism that occurs there. The question is why there is not more. There has been a time span of some 5,000-10,000 years for independent speciation to take place. There are many small islands which favor occurrence of populations varying as a result of random drift, as well as an environment which exerts important stresses by wind, salt spray, drought and insolation, and perhaps formerly by now-extinct herbivores. The answer seems to be the return of new genetic developments to the larger populations in the west, obscuring the extent of differentiation in the eastern populations, and sometimes affecting the parent strains on the western land mass. In other cases, species which developed sufficiently to be distinguished as such may have made the passage downhill (down wind or down stream) intact and taken their places in the flora of the area as a whole rather than as endemics to the eastern edge only.

With the sea level subsidence of Pleistocene glaciations, the Mona Passage may not have been above sea level, and if it was, it was not for long. Puerto Rico and Hispaniola were essentially distinct land masses throughout most of this period. Accordingly, we should not be surprised to find cases where plants evolved on eastern islands and moved westward with wind or currents to Hispaniola. Such is perhaps the case with *Chamaesyce turpinii*, *Croton discolor*, *C. betulinus*, *Cassine xylocarpa*, *Heliotropium crispiflorum* and probably others. Much of the flora of the Bahamas probably was received from the Leeward Islands, the Virgin Islands, and especially Anegada in just such a fashion.

The list of the Anegada flora as now known is too short to come to more than tentative conclusions. Certainly it seems likely that enlargement of the list by further collecting in the immediate future will turn up a number of species and forms, throwing important light on the evolution of many Greater Antilles taxa. The same considerations apply to fresh water algae and fauna, to insects and to other animals. Thomas (1965) has already turned up unexpected patterns in the worm snake genus Typhlops.

CHECKLIST OF ANEGADA FLORA

In the following list of species, nomenclature is corrected from the now discarded American Code names as far as possible, but no recourse was made to type material. Synonyms and wrong author citations are mostly restricted to names used by Britton, but in some cases, other names in current use have been added. All species named without citation of specimens are taken from Britton (1916) or Britton & Wilson (1923-25) whose supporting collections are at New York Botanical Garden (NY). The checklist proceeds in the order of Britton & Wilson, which is essentially that of Dalla Torre & Harms. Specimens have been lodged in several herbaria, e.g. Missouri Botanical Garden (MO), University of Florida, Gainesville (FLAS), Arnold Arboretum (A). Specimens were identified by the author except where noted. Those sent to Mr. Roy Woodbury for identification are at the Agricultural Experiment Station, Rio Piedras, Puerto Rico.

In a few cases, no specimens were taken, but the species was later identified from a color transparency. Citing such ephemeral sources is of course to be frowned upon, but in this case it seems reasonable as only strikingly distinctive plants are so named.

A. ANGIOSPERMS

POACEAE

Arundo sp.
Reported by Schomburgk (1832) but not collected since.

Dactyloctenium aegyptium (L.) Beauv.
D. aegyptium (L.) Willd.

Echinochloa colonum (L.) Link
D'Arcy 2127 (FLAS)

Eragrostis ciliaris (L.) R. Br.
E. ciliaris (L.) Link

Eragrostis urbaniana Hitchc.

Panicum geminatum Forsk.

Panicum _utowanaeum_ Scribn.

Paspalum _laxum_ Lam.
    _P._ _glabrum_ Poir.

CYPERACEAE

Cyperus _cuspidatus_ H.B.K.

Cyperus _elegans_ L.

Cyperus _fuligineus_ Chapm.

Cyperus _planifolius_ Rich.
    _C._ _brunneus_ Sw.

Fimbristylis _inaguensis_ Britt.

Fimbristylis _monostachya_ (L). Hassk.
    Abildgaardia _monostachya_ (L.) Vahl

ARECACEAE

Cocos _nucifera_ L.
        D'Arcy photo

Sabal sp.

Thrinax _morrisii_ Wendl.

BROMELIACEAE

Tillandsia _utriculata_ L.

COMMELINACEAE

Commelina _elegans_ Kunth
    _C._ _elegans_ H.B.K.

LILIACEAE

Aloe _barbadensis_ Mill.
    Aloe _vulgaris_ Lam.
        D'Arcy photo. Naturalized around The Settlement.

AMARYLLIDACEAE

Agave _missionum_ Trel.

Furcraea _tuberosa_ Ait. f.

ORCHIDACEAE

Spiranthes stahlii Cogn. in Urb.
    Mesadenus lucayanus (Britt.) Schlecht.

Tetramicra elegans (Hamilt.)

URTICACEAE

Pilea margarettae Britt.

Pilea microphylla (L.) Liebm.

Pilea tenerrima Miq.

OLACACEAE

Schoepfia obovata C. Wright

LORANTHACEAE

Dendropemon caribaeus Krug & Urb.
    Phthirusa caribaea (Krug & Urb.) Engl.

POLYGONACEAE

Coccoloba krugii Lindau
    Coccolobis krugii Lindau
        D'Arcy 2138, det. R. Woodbury

Coccoloba uvifera (L.) L.
    Coccolobis uvifera (L.) Jacq.
        D'Arcy photo

CHENOPODIACEAE

Salicornia perennis Mill.
        D'Arcy 2120 (FLAS).

AMARANTHACEAE

Achyranthes portoricensis (Ktze.) Standl.

Lithophila muscoides Sw.

Philoxerus vermicularis (L.) Beauv.
    P. vermicularis (L.) Nutt.

NYCTAGINACEAE

Pisonia subcordata Sw.

BATACEAE

Batis maritima L.

AIZOACEAE

Cypselea humifusa Turp.

PORTULACACEAE

Portulaca halimoides L.

Portulaca oleracea L.

CRASSULACEAE

Kalanchoë pinnata (Lam.) Pers.
    Bryophyllum pinnatum (Lam.) Kurz

MIMOSACEAE

Desmanthus virgatus (L.) Willd.
    Acuan virgatum (L.) Medic.

Fishlockia anegadensis (Britt.) Britt. & Rose
    Acacia anegadensis Britt.
        D'Arcy 2124 (FLAS).

Pithecellobium unguis-cati (L.) Mart.

CAESALPINIACEAE

Cassia bicapsularis L.
    Adipera bicapsularis (L.) Britt. & Rose

Cassia glandulosa var. _swartzii_ (Wickstr.) J.F. Macbr.
    Chamaecrista swartzii (Wickstr.) Britt.

Cassia occidentalis L.
        D'Arcy 2123 (FLAS).

Cassia polyphylla Jacq.
    Peiranisia polyphylla (Jacq.) Britt. & Rose

Cassia sophera L.

FABACEAE

Centrosema _virginianum_ (L.) Benth.
    Bradburya _virginiana_ (L.) Ktze.

Crotalaria _lotifolia_ L.

Galactia _dubia_ DC.
        D'Arcy 2116 (MO)

Pictetia _aculeata_ (Vahl) Urb.
        D'Arcy 2135 (FLAS)

Sophora _tomentosa_ L.

Stylosanthes _hamata_ (L.) Taub.

MALPIGHIACEAE

Byrsonima _lucida_ (Mill.) DC.
    _B._ _cuneata_ (Turcz.) P. Wilson

Malpighia _infestissima_ A. Juss. ex Ndz.
    _M._ _infestissima_ (A. Juss.) Rich.

Malpighia _linearis_ Jacq.
        D'Arcy 2121 (FLAS)

Stigmaphyllon _periplocifolium_ (Desf.) Juss.
    _S._ _lingulatum_ (Poir.) Small

RUTACEAE

Amyris _elemifera_ L.
        D'Arcy 2126 (FLAS)

SURIANACEAE

Suriana _maritima_ L.

POLYGALACEAE

Polygala _hecatentha_ Urb.

EUPHORBIACEAE

Argythamnia _candicans_ Sw.
        D'Arcy 2115 (MO)

Argythamnia _stahlii_ Urb.

Chamaesyce articulata (Aubl.) Britt.

Chamaesyce blodgettii (Engelm.) Small

Chamaesyce mesembrianthemifolia (Jacq.) Dugand
    Chamaesyce buxifolia (Lam.) Small

Chamaesyce serpens (H.B.K.) Small

Chamaesyce turpinii (Boiss.) Millsp.
    C. anegadensis Millsp.

Croton betulinus Vahl
        D'Arcy 2113 (FLAS)

Croton discolor Willd
        D'Arcy 2125 (FLAS)

Euphorbia petiolaris Sims
    Aklema petiolare (Sims) Millsp.
        D'Arcy 2137 (FLAS)

Hippomane mancinella L.
        D'Arcy, observation only -- one tree behind Loblolly Bay.

Jatropha gossypifolia L.
    Adenoropium gossypifolium (L.) Pohl
        D'Arcy photo

Phyllanthus polycladus Urb.

CELASTRACEAE

Cassine xylocarpa Vent.
    Elaeodendrum xylocarpum (Vent.) DC.

Crossopetalum rhacoma Cranz
    Rhacoma crossopetalum L.
        D'Arcy 2139 (A), det. R.A. Howard

Gyminda latifolia (Sw.) Urb.
        D'Arcy 2130 (MO)

SAPINDACEAE

Dodonaea viscosa Jacq. var spatulata (J. E. Sm.) Benth.
    D. ehrenbergii Schl.

Serjania polyphylla (L.) Radlk.

RHAMNACEAE

Colubrina arborescens (Mill.) Sarg.
    C. colubrina (Jacq.) Millsp.
        D'Arcy 2128, det. R. Woodbury.

Colubrina reclinata (L'Her.) Brongn.

Krugiodendron ferreum (Vahl) Urb.

Reynosia uncinata Urb.

Zizyphus rignonii Delp.
    Sarcomphalus domingensis (Spreng.) Krug & Urb.
        D'Arcy 2180 (FLAS), det. R. Woodbury; *2140* (MO)

VITACEAE

Cissus trifoliata (L.) L.
    C. trifoliata L.

TILIACEAE

Corchorus hirsutus L.

MALVACEAE

Sida ciliaris L.

Sida procumbens Sw.

STERCULIACEAE

Waltheria indica L.
    W. americana L.

CANELLACEAE

Canella winterana (L.) Gaertn.

TURNERACEAE

Turnera diffusa Willd.
        D'Arcy 2112 (FLAS, MO)

PASSIFLORACEAE

Passiflora suberosa L.
    P. pallida L.

CACTACEAE

Melocactus intortus (Mill.) Urb.
Cactus intortus Mill.

Opuntia aff. dillenii (Ker-Gawl.) Haw.
D'Arcy photo

Pilosocereus royeni (L.) Byles & Rowley
Cephalocereus royeni (L.) Britt.

TERMINALIACEAE

Conocarpus erecta L.

Laguncularia racemosa (L.) Gaertn. f.

MYRTACEAE

Eugenia axillaris (Sw.) Willd.

RHIZOPHORACEAE

Rhizophora mangle L.

THEOPHRASTACEAE

Jacquinia arborea Vahl
J. barbasco (Loefl.) Mez.

Jacquinia berterii Spreng.
D'Arcy 2134 (FLAS)

SAPOTACEAE

Bumelia obovata (Lam.) A. DC.

GENTIANACEAE

Centaurium brittonii Millsp.

APOCYNACEAE

Nerium oleander L.
D'Arcy photo, cultivated at The Settlement

Plumeria alba L.

Urechites lutea (L.) Britt.
D'Arcy 2119 (FLAS)

ASCLEPIADACEAE

Cynanchum anegadense (Britt.) Alain
Metastelma anegadense Britt.

CONVOLVULACEAE

Evolvulus glaber Spreng.

Evolvulus sericeus Sw.

Evolvulus squamosus Britt.
Listed by Britton, but van Ooststroom (1934) did not cite an Anegada specimen for this species.

Ipomoea pes-caprae (L.) Roth
D'Arcy photo -- Loblolly Bay.

Jacquemontia cayensis Britt.

EHRETIACEAE

Bourreria succulenta Jacq.

Cordia bahamensis (Urb.) Millsp.
Varronia bahamensis (Urb.) Millsp.

BORAGINACEAE

Heliotropium crispiflorum Urb.

Heliotropium microphyllum Sw.
H. inaguense Britt.
H. plumerii Urb. & Ekm.
D'Arcy 2117 (FLAS)

Tournefortia gnaphalodes (L.) R. Br.
Mallotonia gnaphalodes (L.) Britt.

Tournefortia microphylla Bert. ex Spreng.
D'Arcy 2129 (MO, FLAS)

VERBENACEAE

Citharexylum fruticosum L.

Clerodendrum aculeatum (L.) Schlecht.
Volkameria aculeata L.

Lantana involucrata L.

LAMIACEAE

Salvia serotina L.
D'Arcy 2114 (FLAS).

SOLANACEAE

Lycium tweedianum var. chrysocarpum (Urb. & Ekm.) C.L. Hitchc.
L. americanum Jacq.
D'Arcy 2136 (FLAS)

Physalis angulata L.

Solanum persicaefolium Dun.
D'Arcy 2154 (FLAS)

BIGNONIACEAE

Tabebuia pallida (Lindl.) Miers
T. heterophylla (DC) Britt.

RUBIACEAE

Erithalis fruticosa L.

Ernodea littoralis Sw.

Exostema caribaeum (Jacq.) R. & S.

Randia aculeata L.
R. mitis L.

Spermacoce tenuior L.

Strumpfia maritima Jacq.
D'Arcy 2141 (FLAS)

CUCURBITACEAE

Cucumis anguria L.

GOODENIACEAE

Scaevola plumieri (L.) Urb.

COMPOSITAE

Borrichia arborescens (L.) DC.

Gundlachia corymbosa (Urb.) Britt.
D'Arcy 2122 (MO)

Pluchea purpurascens (Sw.) DC.

Wedelia parviflora L.C. Rich.
D'Arcy 2131 (MO)

B. BRYOPHYTES

Bryum microdecurrens E. G. Britt.

Hymenostomum breutelii (C. Muell.) Broth.

C. CHAROPHYTES

Chara sp.

D. LICHENS

Anthracothecium libricolum (Fée) Muell.-Arg.

Arthonia interducta Nyl.

Arthonia anegadensis Riddle

Arthopyrenia fallax (Nyl.) Arnold

Buellia parasema var *aeruginascens* (Nyl.) Muell.-Arg.

Glyphis cicatricosa Ach.

Pyxine meissneri Tuck.

Ramalina denticulata (Eschw.) Nyl.

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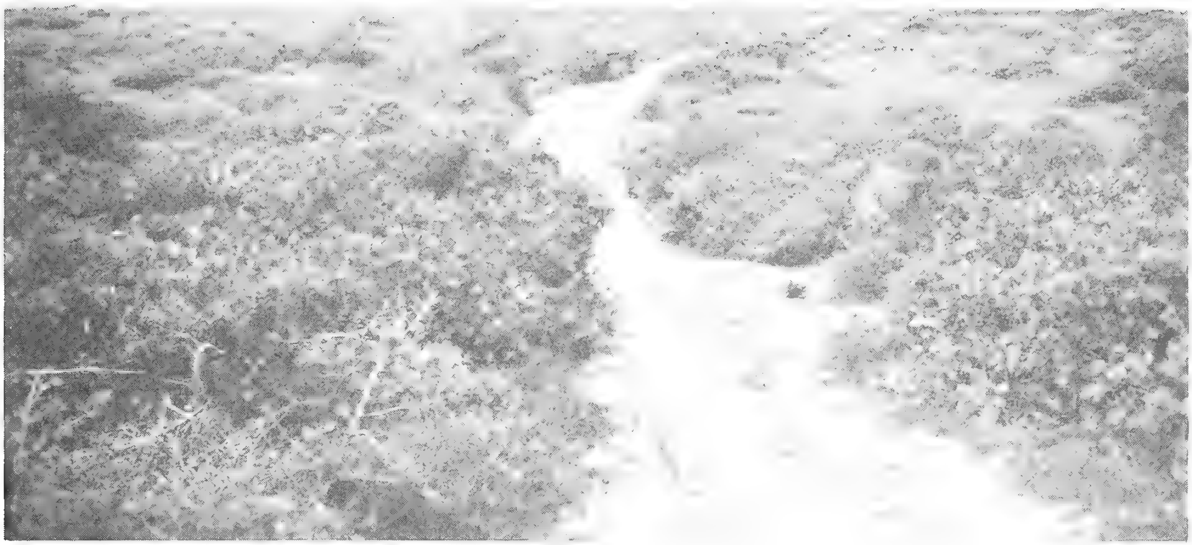

Plate 1. View of Anegada from near Loblolly Bay looking to the southwest. Virgin Gorda is to be seen in the distance.

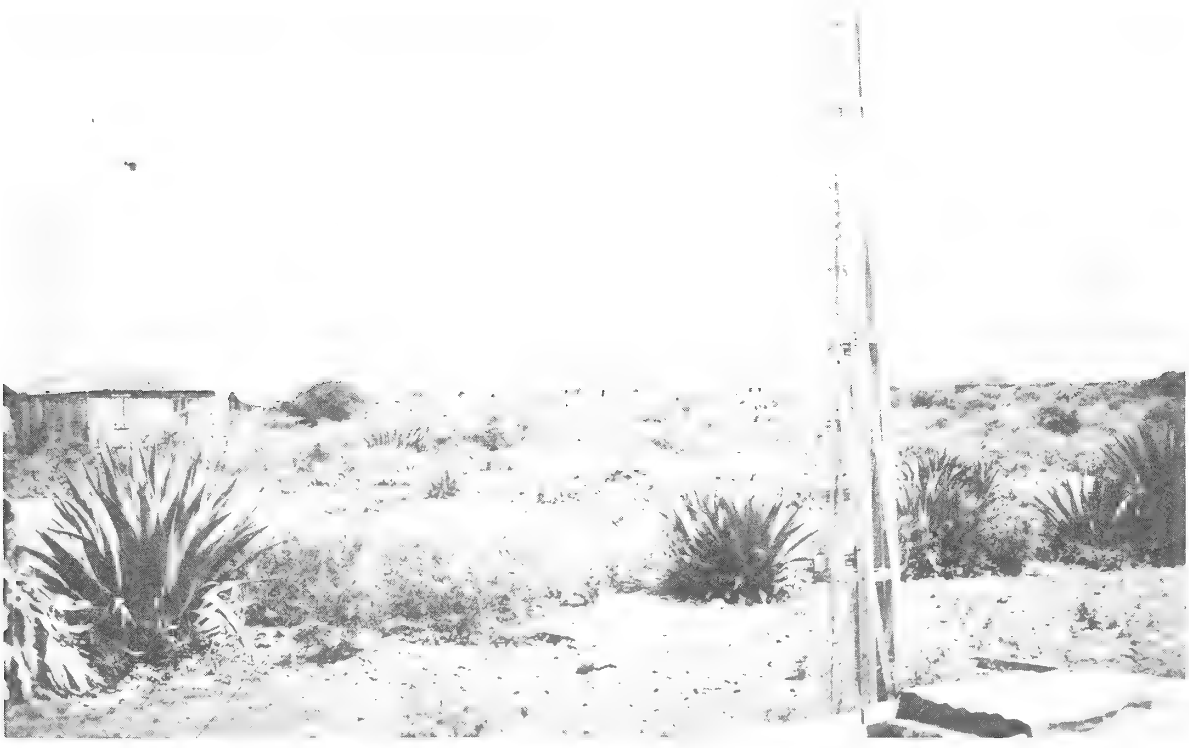

Plate 2. View of the landscape at The Settlement showing the extent of overgrazing.

Plate 3. Large Pisonia tree showing planing of the top by the winds.

Plate 4. View of the rocky plain between Loblolly Bay and The Settlement.

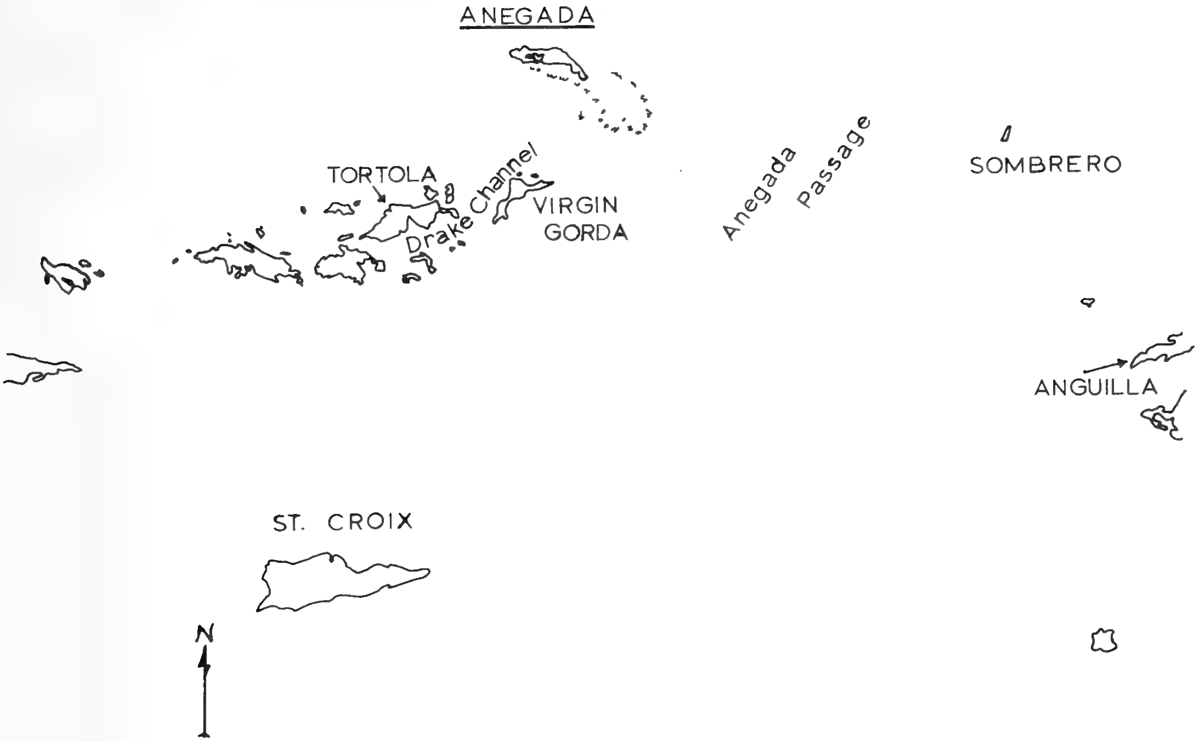

Plate 5. Map showing Anegada in relation to the Virgin Islands.

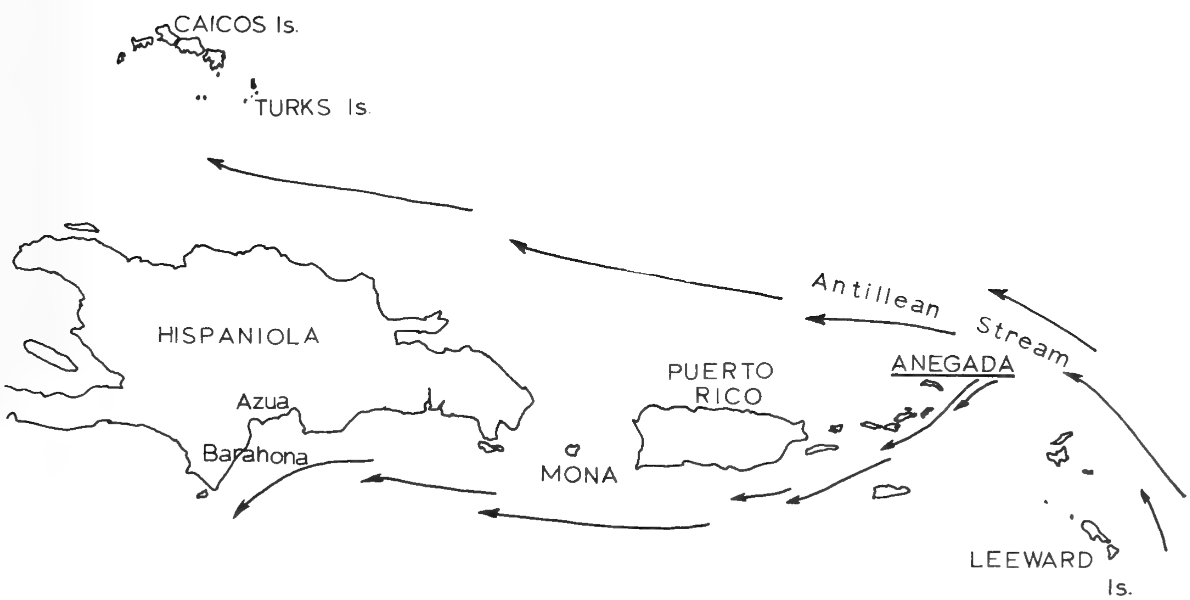

Plate 6. Map showing Anegada in relation to ocean currents and the islands to the west.

ATOLL RESEARCH BULLETIN

No. 140

INSHORE MARINE HABITATS OF SOME CONTINENTAL ISLANDS IN THE EASTERN INDIAN OCEAN

by Alan J. Kohn

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INSHORE MARINE HABITATS OF SOME CONTINENTAL ISLANDS IN THE EASTERN INDIAN OCEAN

by Alan J. Kohn [1/]

Auxiliary Cruise A of the U. S. Program in Biology, International Indian Ocean Expedition, provided the opportunity for field observations of inshore marine habitats of several groups of continental islands off the west coasts of the Malay Peninsula and Sumatra. The research vessel *Te Vega* left Singapore 15 October 1963 and terminated the cruise at Padang, Sumatra, 16 December 1963. During this period it was possible to devote 32 days to field study of coral reefs and other shore habitats. My main research emphasized the comparative ecology of the gastropod genus *Conus* in habitats supporting many co-occurring species and will be published elsewhere.

This paper, based mainly on field notebooks, lists and describes features of habitats at 15 stations in Thailand and Sumatra, most of which were on remote and very poorly known islands. I am not aware of any previous information on coastal formations of the islands west of Thailand, and none of the Indonesian sites studied are discussed in accounts of East Indian coral reefs (Kuenen, 1933; Umbgrove, 1947). Fig. 1 shows the track of Auxilary Cruise A.

Place names used are from British Admiralty charts, sometimes followed by alternate names in parentheses from U. S. Naval Oceanographic (formerly Hydrographic) Office charts and from Pilots or Sailing Directions. Coordinates refer specifically to *Te Vega Stations*.

Distances are in metric units, but water depths and other vertical distances are in feet to conform with tide tables and charts. Tidal data are from U. S. Naval Oceanographic Office and British Admiralty charts and U. S. Coast and Geodetic Survey Tide Tables. All sea surface temperatures recorded at nine stations ranged only from 30.0° to 32.0°C.

Particle size distributions of sand samples were analyzed by the settling tube method of Emery (1938).

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THAILAND: SINDARAR ISLANDS (CHANCE ISLANDS)

Two large, high (1100-1200 feet), densely wooded islands, Goh Sindarar Nua and Goh Sindarar Tai, are the northernmost offshore islands belonging to Thailand. They are about 90 km NNE of Goh Similan, and likewise about 65 km offshore. However, the continental shelf is wider here, and the islands lie about 40 km east of the 100-fathom line.

Goh Sindarar Nua. 9°25'30"N, 97°34'00"E. *Te Vega* Sta. 82. 5-7 November 1963.

A shallow, narrow channel separates the two Sindarar Islands, but the channel does not penetrate the fringing reef on the west side (Fig. 2). Both islands have irregular shorelines characteristically with large, weathered boulders above the beach and narrow fringing reefs.

Our studies concentrated in the large, southeast-facing embayment (Fig. 2). The fringing reef along the west shore near the mouth of the bay (Sta. 82A) has a substrate of patches of sand of varying particle size distribution (Table 1) and reef limestone outcrops inshore, and of reef limestone and low, dead coral heads nearer the outer edge, where living corals are also abundant. The reef flat is at about the -0.6'-+1.2' level. (Tidal datum is datum of Admiralty Chart 3052 and of Coast and Geodetic Survey Tide Tables and is 0.9' below MLWS).

The reef platform surrounding the western extremity of the bay is deeper, at about the -5' level. Large areas of sand strewn with coral rubble and isolated *Porites* heads about 2 m in diameter and 1-2 m high characterize the area examined (Sta. 82B, Fig. 2). Denser and more diverse corals, mainly *Porites lutea* and *Acropora* spp., occur in a band about 10 m wide along the outer reef margin.

The inshore area of the fringing reef along the northwest side of the bay (Sta. 82C, Fig. 2) is of sand (Table 1), with some truncated reef limestone covered with a thin layer of sand. *Porites lutea* again dominates the offshore portion, but some *Acropora*, *Millepora*, *Diploastrea*, *Goniastrea*, and other genera occur also (all coral specimens collected are presently at the Smithsonian Oceanographic Sorting Center). Living and dead coral heads are the predominant substrate, with some reef limestone, at about the -2.5' level. Some areas are paved with large pieces of *Acropora* rubble. Below about -3' are large areas of sand with sparse but large coral knolls, usually of several species, growing on a founder head most often of *Porites*.

Mangroves (*Rhizophora*) border the head of the bay (Sta. 82D, Fig. 2). One small stream, brackish at the time of observation, enters. Poorly sorted sand (Table 1) is the dominant substrate, but there is one outcrop of conglomerate rocks and a few dead coral heads. An enteropneust (*Saccoglossus*?), the gastropod *Conus eburneus*, and the alga *Halimeda* were the commonest large organisms present.

The one site visited on the reef fringing Goh Sindarar Tai (Sta. 82E) had a substrate of coral rubble and isolated Porites heads and Acropora thickets at about the -2.5' to -4.5' level.

THAILAND: SIMILAN ISLANDS (SAYER ISLANDS)

Three groups totaling nine high, wooded islands in a north-south line comprise the Similan Islands, in the Andaman Sea near the edge of the continental shelf, about 65 km west of Lem Tam Chok (Lem Tham Tjob, or Cape Dolphin) in approximately 8°28' - 8°41'N, 97°38' - 97°41'E.

Goh Huyong (South Island). 8°28'50"N, 97°39'00"E. Te Vega Sta. 77; 3-4, 8 November 1963.

Goh Huyong, the southernmost of the Similan Islands, has on its northeast side the only sand beach and coral reef mentioned in the Sailing Directions (U.S. Navy Hydrographic Office, pub. 160, 1951) as occurring in the archipelago; the rest of the island is steep-to.

The reef (Figs. 3-5) is exposed to heavy wave action, and at the highest spring tides (about +9') heavy breakers crash on the beach to the level of upper beach vegetation. Seaward of the sand beach is a band 10-20 m wide (zone 1, Figs. 3,4) of solid, rather smooth reef limestone platform covered with a thin layer of sand. Large pieces of rubble occur here; the only deeper sand patches occur inshore, where beach sand appears to be constantly rearranged by the waves. The sand is predominantly fine and medium (Table 1), entirely calcareous, and fragments of the calcareous green alga Halimeda are conspicuous in it. The sand probably scours the reef limestone, smoothing it and keeping it free of attached organisms. Zone 2, a moat, 3-8 inches deeper than the adjacent reef limestone, occurs intermittently at 20-55 m from shore. Zone 2', beginning about 40 m, is similar except that Halimeda is present. From there seaward it becomes a prominent feature of the reef; several species are abundant over the broad third zone of the reef platform (Figs. 3,5). Halimeda must contribute importantly to the beach sand, which is poorly sorted and coarser than that on the reef platform (Table 1).

Further seaward (zone 4), the reef substrate appears less influenced by sand transport; perhaps the central and outer regions are swept clear of sand by stronger water movements. "Wheels" of Porites (probably P. lutea), cemented to the reef and growing only at their peripheries, occur sparsely from about 55 m and become prominent features further seaward (Figs. 3,5). In this region also are some tide pools varying in depth from a few inches to 2-3 feet.

Beyond 140 m (zone 4), living coral is more varied. Heliopora coerulea is prominent in some areas, members of the genera Acropora, Montipora, Scaphophyllia, Psammocora, Goniopora, and Goniastrea were also noted, and more rubble is deposited on the intervening reef

limestone. However, there are no areas of sand, although sand is of course deposited at greater depths outside the zone of breaking waves. Below about -12', the sandy areas are larger, and coral heads are sparse. The slope appears to be quite gradual from this depth to about -60'.

In some regions, particularly on the east side of the reef, the seaward rampart is higher, with boulders and large pieces of coral rubble (zone 5).

Goh Similan (Great Sayer Island). 8°38'45"N, 97°39'10"E. *Te Vega* Sta. 85; 8 November 1963.

A brief stop at a bay on the east side of Goh Similan revealed an inshore region with a substrate of fine sand with outcrops of truncated reef limestone, and an outer region of sand with large, sparsely distributed coral heads, mainly of *Porites* but also including some *Heliopora*.

THAILAND: KO PHUKET (SALANG or JUNKSEYLON ISLAND)

Reef west of airport, Ko Phuket. 8°6'15"N, 98°18'10"E. *Te Vega* Sta. 90. 17 November 1963.

The reef fringes the northernmost of several bays indenting the north-south trending west coast of the island. Seaward of a shallow longshore moat with dead coral heads on rather fine sand, the main portion of the broad fringing reef is at about the 0 to -1.6' level (Datum is of soundings on Admiralty Chart 3941 and of Coast and Geodetic Survey Tide Tables and is 0.9' below MLWS).

Porites lutea dominates the flat and appears to be the most important hermatypic species. Most heads are growing only at the edges, their upper surfaces evidently scoured by sand in the water. Further seaward, the coral fauna is more varied, but mainly of low growth form. Some sand-filled depressions occur among the coral heads; some of these contain *Acropora*.

Ao Pa Tong. 7°53'15"N, 98°17'00"E. *Te Vega* Sta. 91. 17 November 1963.

Ao Pa Tong is the most enclosed bay on the west side of Ko Phuket. The station, on the southern side of the bay, is an intertidal platform at about the +2.5' level, composed of very rough and irregular reef limestone outcrops with a thin layer of sand in crevices (Table 1).

THAILAND: KO PHI PHI

Ko Phiphidon. 7°46'20"N, 98°44'25"E. *Te Vega* Sta. 87. 9, 15 November 1963.

Little can be reported from our brief visit to Ko Phiphidon, the largest of a group of four islands about 40 km ESE of Phuket. The

island is crudely H-shaped, with sheer limestone cliffs and wooded peaks rising to 1100 feet. The bay on the north side of the isthmus of the "H" is a sandy cove, with dead reef in the center and actively growing coral reef along the outer portion across the mouth of the bay.

THAILAND: PULO TA NGAH

Pulo Ta Ngah (Tengah, Tenga). 6°34'24"N, 99°27'36"E. *Te Vega* Sta. 88. 10, 14 November 1963.

Pulo Ta Ngah lies about 40 km offshore and about midway between the offshore Butang Islands and Ko Terutao, just north of the boundary with Malaysia. The surrounding water is 10-20 fathoms deep. About 3 km long and 650 ft high, the island consists of north and south islets connected by a reef, which continues as a fringing reef on the east side, roughly 300 m wide at the point of examination. The following zones were distinguished:

Beach: steep; width 46 m.

1: Inner margin of reef platform: coarse sand (Table 1) with cobbles and isolated outcrops of smooth, truncated reef limestone; width about 15 m.

2: Rougher reef limestone covered with a thin layer of sand (Table 1); width 38 m.

3: *Porites lutea* heads and wheels, both loose on thin to deep sand (Table 1) and cemented to the reef limestone; dead coral heads and boulders also present; width 50 m.

4: The major portion of the reef platform: a plain of low growing *Acropora*, interspersed with a few *Porites* heads and dead coral rocks; width about 160 m.

Because of apparent disagreement of tidal levels with the nearest station of daily tide predictions (Pulo Lila, 24 km NW), it was not possible to estimate the level of the reef platform with respect to tidal datum.

INDONESIA: SUMATRA AND OFFSHORE ISLANDS

Pulo Boenda (Boenta). 5°33'15"N, 95°9'00"E. *Te Vega* Sta. 93. 20 November 1963.

Pulo Boenda is about 2.2 km long and lies offshore about 3 km northwest of Acheh Head, the northwest extremity of Sumatra. According to the sailing directions (Hydrographic Office Pub. 162, 1951), the island is covered nearly to its 778' summit with casuarina trees, but in 1963 it was covered to within 100' of the summit with coconut palms.

A heavy swell, 2-3' high, broke on the narrow (less than 100 m wide) fringing reef on the west side of the island during our visit. The following zones were distinguished:

Beach: Very narrow; sand and cobbles.

1: Moat at level of tidal datum (=MLWS); substrate of smooth truncated reef limestone pavement covered by a thin layer of sand.

2: Abundant zoanthids (colonial, sea anemone-like coelenterates) and relatively smooth truncated limestone; +2.5'.

3: A broad region dominated by *Tubipora*, *Acropora*, and zones of *Acropora* rubble and smooth, reef limestone pavement.

4: Seaward reef margin: slopes gently seaward, with abundant cementing calcareous red algae; heavy surf.

5: Upper portion of reef front: substrate solidly of low, growing coral colonies.

Pulo Penju. 2°50'57"N, 95°56'35"E. *Te Vega* Sta. 97. 22 November 1963.

Pulo Penju is one of many small coral islands around Simalur (Simueleu), the northwesternmost of the large, high islands off the west coast of Sumatra. It lies about 2.5 km off the north side of Simalur and is joined to another small island to the northeast, Pulo Kitjik, by a reef extending the mile between them. The following zones could be distinguished on the fringing reef extending about 75 m eastward from the east side of Penju:

1: Moat with coral rocks and slabs on sand (Table 1) and much terrigenous debris, mostly from coconut palms; width 3-6 m; +0.5-+1' level (Datum = LWS).

2: Inner reef margin: *Acropora* rubble with some dead coral slabs on rubble and sand (Table 1). Width 30-37 m; +1' level.

3: Large dead slabs and heads on rubble; some large dead coral heads cemented to reef limestone. Horizontally irregular ridges and depressions about 2' deep; width 10 m.

4: Large coral heads on rubble; some sand; width 14 m; -2.5' level.

5: Outer reef margin; width 15 m.

Along the southeast corner of the island Zone 2 is a complex region mainly of unconsolidated *Acropora* rubble piled up in a rampart about 2' high with scattered dead coral slabs and "coolie hats" resting on it. The highest portions were at the +1.5' level.

Pulo Pandjang, Banjak Group. 2°15'50"N, 97°24'15"E. *Te Vega* Sta. 98A, 23 November 1963.

The Banjak (Banyak) Group consists of more than 50 islands about 30-70 km west of Singkel, Sumatra, and between the larger islands of Simalur and Nias. Pulo Pandjak is one of the Delapan Islands, of which Ujung Batu is the largest, on the northeast margin of the Banjak Group. The Delapan Group "is nearly completely surrounded, and the individual islands are mutually connected by coast reefs, which largely dry at low water" (Hydrographic Office, Pub. 162, 1951).

Our observations were restricted to the central region of the very broad reef (900 m wide) fringing the southwest side of Pulo Pandjang. The substrate is of large areas of sand (Table 1) with scattered coral rubble and isolated living and dead coral heads.

Pulo Melila, Banjak Group. 2°15'15"N, 97°25'12"E. *Te Vega* Sta. 98B. 23 November 1963.

The reef area on the north and east sides of Melila, a small double islet on the reef extending from Pulo Rangit Besar to Pulo Pandjang is about 200 m wide and topographically somewhat more complex than Sta. 98A. Two zones were distinguished:

1: Inshore portion of reef platform: isolated outcrops of cemented coral heads surrounded by large areas of rather coarse sand (Table 1). *Halimeda opuntia* very common.

2: Offshore portion of reef platform: extensive areas of growing coral. *Porites lutea* prominent in some areas and *Acropora* in others, forming thickets to 2' above the sand (cf. Fig. 7).

Pulo Bai, Batu Group. 00°01'45"S, 98°31'15"E. *Te Vega* Sta. 101, 25-27 November 1963.

The Batu Islands are a complex of three large and several small islands and many reefs, straddling the equator at 98°-99°E longitude, between the larger islands of Nias and Siberut.

Pulo Bai is about 5 km long with four large, broad fringing reef areas extending from the southeast, east, northeast and north sides. The shore on the north end of the island is a vertical cliff 4-6' high of fossil-bearing siltstone. A transect of the reef extending northward from it revealed the following zones:

1: Inner reef margin: moat with substrate of silt and sand, apparently mainly of terrigenous origin. Width 16 m; +0.4' level (Datum = MLWS).

2: Sand substrate, *Cymodocea* (?) bed with other organisms. *Holothuria atra* and brown sponge common. Width 27 m; +0.9' level.

3: Halimeda sand on truncated siltstone; sponges and Cymodocea sparse. Width 4 m.

4: Rough reef limestone. 4a: reef limestone outcrops; prominent algae are Turbinaria and Caulerpa; width 35 m. 4b: reef limestone interspersed with small sand patches; algae sparser; width 11 m. 4c: reef limestone with isolated small faviid corals; very little sand; width 9 m. 4d: reef limestone with coral heads more common; Porites lutea and Pocillopora damicornis predominate; width 22 m; +0.9' level.

5: Acropora rubble. 5a: with some small faviid heads and living Acropora colonies; width 5 m. 5b: dead coral slabs on pebble to cobble size (Table 1) rubble; width 7 m (Fig. 6).

6: Outer portion of reef platform: downward slope begins; more rough reef limestone, less rubble present; width 145 m; -0.6' level at 146 m from shore (beginning Zf zone 6).

7: Reef front: gentle slope of Zone 6 continues to edge of sand at -4.5' level.

Other portions of the outer reef platform and gently sloping reef front vary considerably in substrate composition. Abundant Pocillopora damicornis, with some Porites and other genera on rough limestone, interspersed with sand patches (Table 1), characterize some areas (Fig. 7). In other portions, thickets of Acropora or patches of complex assemblages of corals separated by sand (Figs. 8-10), or more extensive areas of varied corals cemented to rough reef limestone (Figs. 11, 12) occur.

Pulo Siburu (Siboeroe), Mentawei Islands. 1°59'45"S, 99°35'00"E. Te Vega Sta. 103: 30 November - 1 December 1963.

Pulo Siburu is one of a complex of small islands extending northeastward from the north tip of the large island of Sipora and with the coast of the latter forming a protected bay, Siburu Bay.

Sta. 103, on the south coast of Pulo Siburu in the bay is an extensive area of sand mainly at the 0 to -2' level (datum = MLWS) where examined. Some outcrops of reef limestone and areas of coral rubble occur (there are reefs nearby) and the inshore, intertidal portion is a dense bed of Cymodocea growing in sand.

Unnamed island in Veeckens Bay, South Pagi Island, Mentawei Islands. 3°14'36-40"S, 100°25'54"-100°26'06"E. Te Vega Sta. 105, 2 December 1963.

Veeckens Bay, between the southwestern end of South Pagi Island and a group of islands off its southeastern point, contains a number of small islands.

Sta. 103 is a low, somewhat elliptical, unnamed island about 1.8 km long and 1 km wide, about 6.5 km east of the western shore of the bay (Fig. 13). Intertidal flats of irregular, rough altered reef rock and detrital conglomerate limestone extend from the northwest and southeast ends of the island. The former appear derived from a coral reef that was uplifted at least 2-3 feet and closely resemble the elevated reef rock ("feo") of the Tuamotu Islands described by Stoddart (1969: see especially Pl. 20). The beach is very narrow and of coarse sand and rubble (Fig. 14) or boulders (Fig. 15). The rock is deeply pitted and very hard. The southeast side of the island is most exposed to the sea; here the surf breaks heavily and there are many coral boulders on the beach (Fig. 15). On the southwest and west sides, the limestone is smoother, especially so in channels (Fig. 17) that widen to about 1-3 m and are about 1' deep. Figure 17 also shows the extensive solution pitting. Some portions of the pitted zone are relatively unweathered and show the remains of corals in position of growth (Fig. 18). Inshore, a very thin layer of algae coats the substrate only in places; it is rarely dense enough to bind any sand. Green algae become more abundant further out, and the seaward margin of the bench bears a veneer of calcareous red algae, probably *Porolithon*.

Mangroves appear to be encroaching on the bench (Fig. 15).

The features of the shoreline of this island suggest that land forms in Veeckens Bay are changing rapidly, a view supported by evidence of erosion of the sandy shore of an adjacent, small, also unnamed island.

Pulo Stupai (Stoepai), Sanding Island, Mentawei Islands. 3°26'50"S, 100°40'50"-100°41'00"E. *Te Vega* Sta. 108, 4-7 December 1963.

Sanding Island, 20 km southeast of South Pagi Island, and 110 km west of Seblat, Sumatra, is the southernmost of the Mentawei Islands. Of all the islands off the west coast of Sumatra, Sanding most closely resembles an atoll (Figs. 19, 20), and further information on its geology would be most interesting. The main island is about 5.1 x 2.4 km low and densely vegetated. It lies near the southwest margin of a broad reef platform, the rim of which is lined with 17 other small, low islets varying from densely vegetated islets to sand cays. Three channels on the east side of the reef lead to broad inlets reaching depths of 10-18 fathoms; this complex approaches a lagoonal structure.

Pulo Stupai, the second largest of the islets, is about 610 x 120 m. The reef, partially drying at low tide, fringing the north and northeast sides of Stupai is Sta. 108A. The western portion of the area examined (Fig. 19) is a platform of rough reef limestone, with some low-growing coral, chiefly *Pocillopora*. Its level is at +0.5 to -1.1' (datum = MLWS). A transect across the eastern portion of the Station revealed the width of the platform to be 175 m to the zone of breaking surf and the heads of surge channels at the outer reef margin. This is almost

twice the width shown in the largest scale chart of the island (Fig. 20), based on a 1917-1918 survey. The entire platform is within one foot of the +0.5' level. It is not sharply zoned, but the following regions could be characterized:

1: Inner margin of reef platform: small dead coral heads, areas of dense coral rubble, few small Porites lutea heads, narrow bands of sand (Table 1) and smooth, truncated reef limestone 1 m wide, and a band of rubble 11 m wide with dead coral slabs occur near the outer margin. Width 40 m.

2: Smooth to rough limestone bench; few live P. lutea heads, scattered dead coral boulders about 0.1 square meter in area on bench, some cemented to reef limestone; algae on smoother portions bind sand; rubble collects in shallow crevices and sand (Table 1), gravel and pebble-sized particles in many deeper depressions, to 0.5' below platform level; Conus spp. common from this zone outward. Figs. 21, 22 show this region, 85 m from shore. Width 60 m.

3: Reef limestone much rougher, making substrate topographically more complex, with more dead coral heads, both loose and cemented (Figs. 23, 24); sand and rubble (pebble to cobble size) mixed with sand in depressions. Halimeda macrophysa common, H. micronesica present. The enteropneust Ptychodera flava is common in sand pockets; mean overall density was 1-1.5 per square meter. Width 25 m.

4: Increasing irregularity and complexity of surface (Fig. 25); small living coral colonies (Pocillopora, Acropora) present. Many loose small boulders and large cobbles on sand; depressions 0.5' deep contain Halimeda sand, with gravel, pebble, and small cobble-sized rubble on sand. Halimeda macrophysa more abundant, H. opuntia common; Jania (branching calcareous red alga) present, forming small thickets. From about 130 m from shore, small colonies of Pocillopora damicornis and Porites lutea become more common. Surge increases at about 140 m from shore, which is also inshore margin of distribution of Latirolagena smaragdula, a characteristic gastropod of the outer portions of the reef. Width 30 m.

5: Seaward reef margin; Porolithon cements loose particles and forms a veneer; heavy surge. Halimeda opuntia common, H. macrophysa present, Caulerpa spp. abundant. Little rubble is present where most waves (1-1.5' high at time of observation) break at the outer edge of this zone, ca. 170 m from shore (Fig. 26). Heads of surge channel at ca 175 m from shore. Width 20 m.

6: Upper portion of reef front: surge channels ca. 1 m wide, 1.5' deep (-0.7' level) at 185 m from shore; their substrate is limestone with a thin algal turf binding sand, and a few boulders. The intervening ridges are topped with many small coral colonies, mainly Pocillopora damicornis and P. eydouxii. The cowry Cypraea caputserpentis

occurs commonly in crevices, and an unidentified black sea urchin, possibly Echinometra sp., bores rather deeply into the substratum. At about 220 m from shore, the distance between surge channels varies greatly but averages about 2 m, and they are about 3' deep (-2.2' level); the reef front slopes gently seaward from this point at about the same grade (about 1.3%) to at least the -20' level. Width examined 50 m.

Sta. 108B, 3°26'32"S, 100°40'47"E,. The islet just northwest of Pulo Stupai (Figs. 19, 20) is a small sand cay surrounded by reef. Sta. 108B, on the southeast side of the islet at the 0 to -1' level, was characterized by unusually dense growths of Halimeda micronesica, H. macrophysa, and Halimeda sp. growing in thick clumps on dead branching coral.

Mega Island, Mentawei Islands. 3°59'44"S, 101°03'02"E. Te Vega Sta. 106, 3 December 1963.

Mega lies 60 km southeast of Sanding and 100 km southwest of Seblat, Sumatra. It is low, roughly elliptical, the long axis in a southwest-northeast direction, and measures about 1.5 x 2 km. It is completely surrounded by a fringing reef 60-465 m wide, on which heavy surf breaks.

The portion of the reef platform examined, at the northeast end of the island, is about 155 m wide and resembles that at Sta. 77, but presents evidence that it is an uplifted reef now being planed down by the sea. Much of the reef platform is at about the +1' to +1.5' level (datum = MLWS) with several large dead coral heads extending to 2' above the platform. These and the higher portions of the platform are of more or less pitted reef limestone, much altered and hardened from their condition in life.

Much of the reef surface, particularly inshore, is of very rough reef limestone with some sand pockets. The outer portion is smoother limestone with an algal film. There are some level areas of coral rubble, a few loose boulders, and coarse sand and gravel derived primarily from Halimeda segments. Several species of Halimeda are abundant on the reef; it is the only alga that binds sand.

SUMMARY

This paper describes and illustrates the surface geomorphology, zonation, and dominant benthic invertebrates and plants of coral reefs fringing the continental islands Similan, Sindarar, and Ta Ngah, Thailand, off the west coast of the Malay Peninsula; and Boenda, Penju, Pandjang, Bai, Sanding, and Mega, off the west coast of Sumatra. A few intertidal reef limestone shores and bays with sand substrate in the same region are also described.

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Table 1.

PARTICLE SIZE DISTRIBUTION OF SUBSTRATE SAMPLES FROM INSHORE HABITATS OF ISLANDS OFF WEST THAILAND AND SUMATRA

Station	Sample No.	Pebbles or Large Shell Fragments Present	Per Cent Composition of Sand Sample					Silt+ Clay 0.0625
			Very Coarse 1-2 mm	Coarse 0.5	Medium 0.25	Fine 0.125	Very Fine 0.0625	
82A	6017	+	6	19	10	51	14	
82A	6021	+	27	13	10	38	12	
82A	6025	+	51	17	15	14	3	
82C	6009		2	8	18	58	14	*
82C	6010		5	17	55	17	6	
82D	6037-9	+	27	17	20	16	9	11
77	reef zone 3-4			1	27	68	5	
77	beach		4	23	43	30		
88	6080 (zone 1)	+	45	39	15	1		
88	6099 (zone 2)	+	5	27	34	24	10	
88	6090 (zone 3)	+	6	29	48	15	2	
88	6101 (zone 3?)	+	32	48	18	2		
91	6132		1	3	93	3		
97	6171 (zone 1)	+	28	26	26	18	2	
97	6172 (zone 1)	+	52	25	13	8	2	
97	6158 (zone 2)			3	23	71	3	*
97	6165 (zone 2)	+	24	21	19	26	10	
98A	6258	+	37	20	19	12	12	
98B	6241 (zone 1)	+	23	20	32	24	1	
98B	6245 (zone 1)	+	22	27	24	20	7	
98B	6246 (zone 1)	+	28	21	31	18	2	
98B	6257 (zone 1)	+	56	22	20	2		
101	6313 (zone 5)	Mainly pebbles						
101	6338 (Outer reef platform)	+	40	38	21			
108A	7274 (zone 1)	+	11	37	47	5		
108A	7272 (zone 1)		20	42	36	2		

*silt-clay fraction detectable but less than 2% of total sample

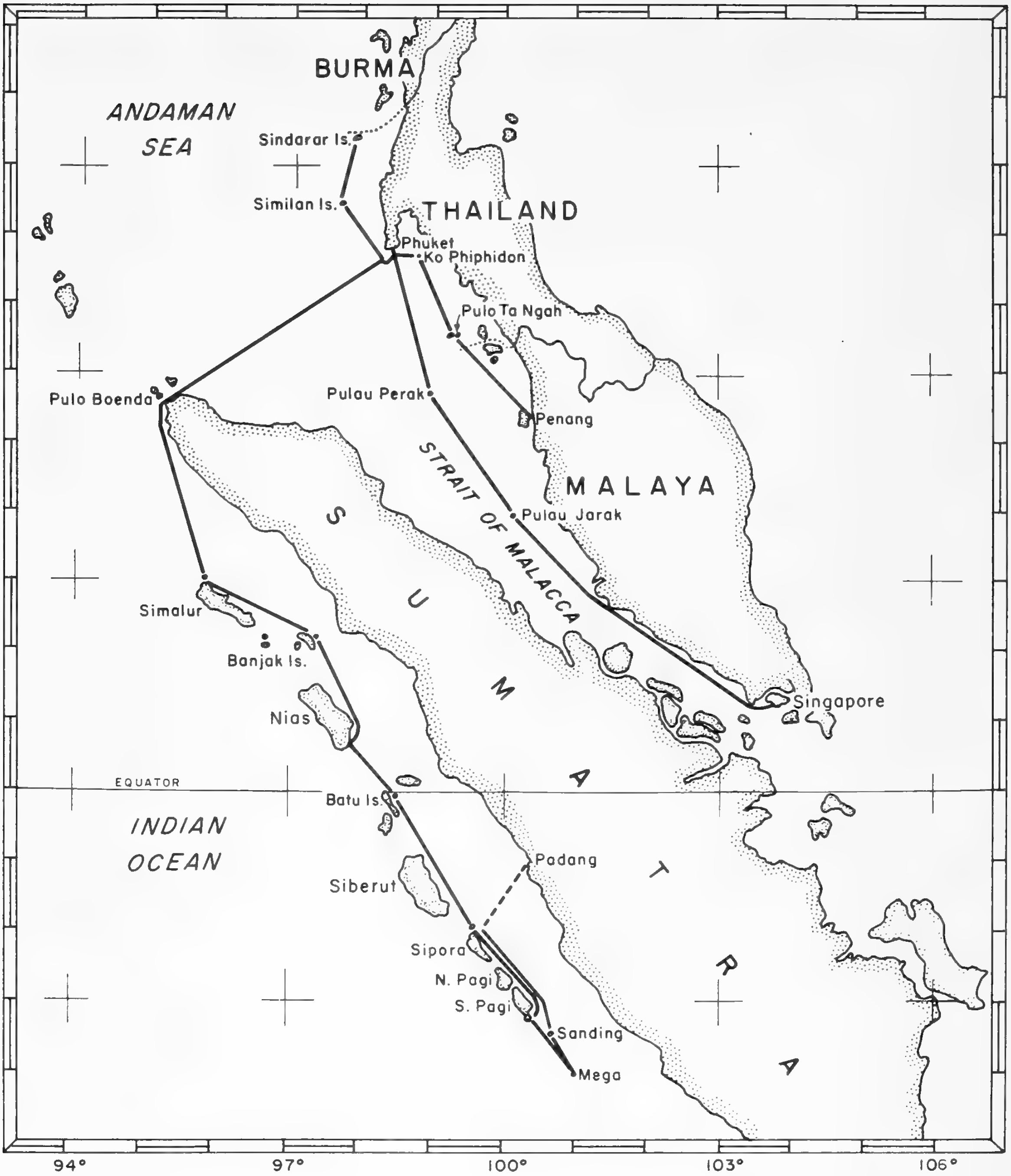


Fig. 1. Map of the southern Malay Peninsula and Sumatra, showing the track of Auxiliary Cruise A of the Te Vega, U. S. Program in Biology, International Indian Ocean Expedition, October-December, 1963.

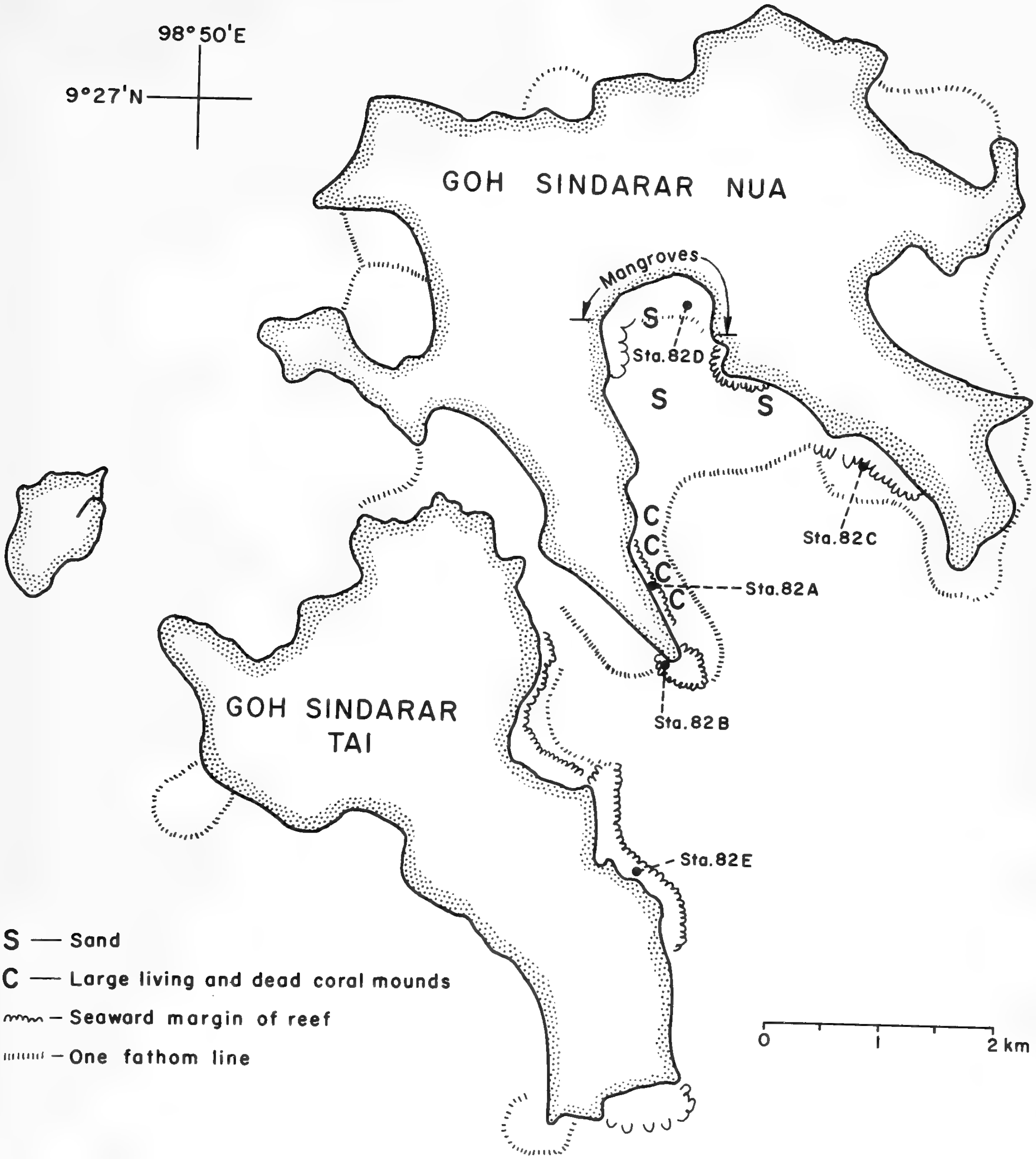
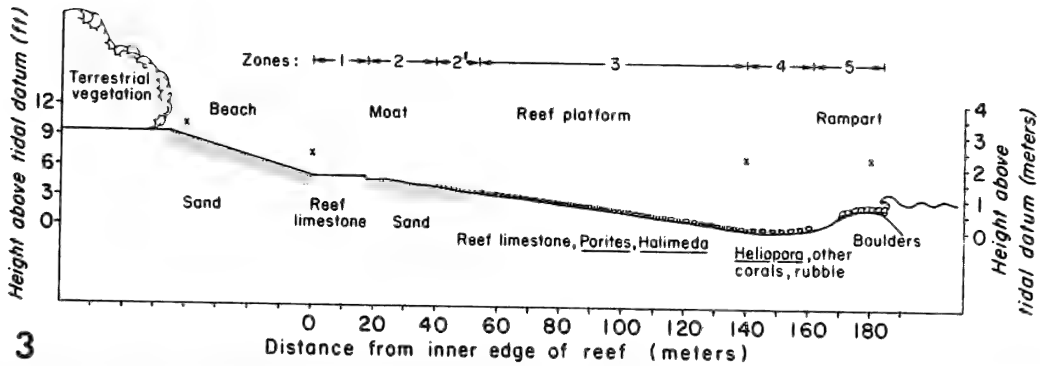


Fig. 2. Sketch map of Goh Sindarar, Thailand (Sta. 82), showing stations and shore features. Based on Admiralty Chart 3052.

Fig. 3. Profile of the fringing reef at Goh Huyong, Similan Islands, Thailand (Sta. 77). Tidal datum is datum of Admiralty Chart 3052 and of Coast and Geodetic Survey Tide Tables and is 1.1' below MLWS. For explanation of zones, see text. X, locations of substrate samples. Vertical exaggeration is 10X.

Fig. 4. Overall view of the fringing reef at Goh Huyong (Sta. 77), taken when tide level was approximately +1.5'.

Fig. 5. Detail of reef surface at Goh Huyong (Sta. 77) in Zone 3, 70 m from inner edge, showing flat, wheel-like colonies of *Porites*, cemented to the underlying reef limestone and growing only peripherally, and clumps of *Halimeda*. P, living portions of *Porites* colonies; H, *Halimeda*. The white vial cap is 40 mm in diameter.


Zones: 1 2 2' 3 4 5
Terrestrial vegetation
Beach
Moat
Reef platform
Rampart
Sand
Reef limestone
Sand
Reef limestone, Porites, Halimeda
Heliopora, other corals, rubble
Boulders
Height above tidal datum (ft)
Height above tidal datum (meters)
Distance from inner edge of reef (meters)
0 20 40 60 80 100 120 140 160 180

3

4

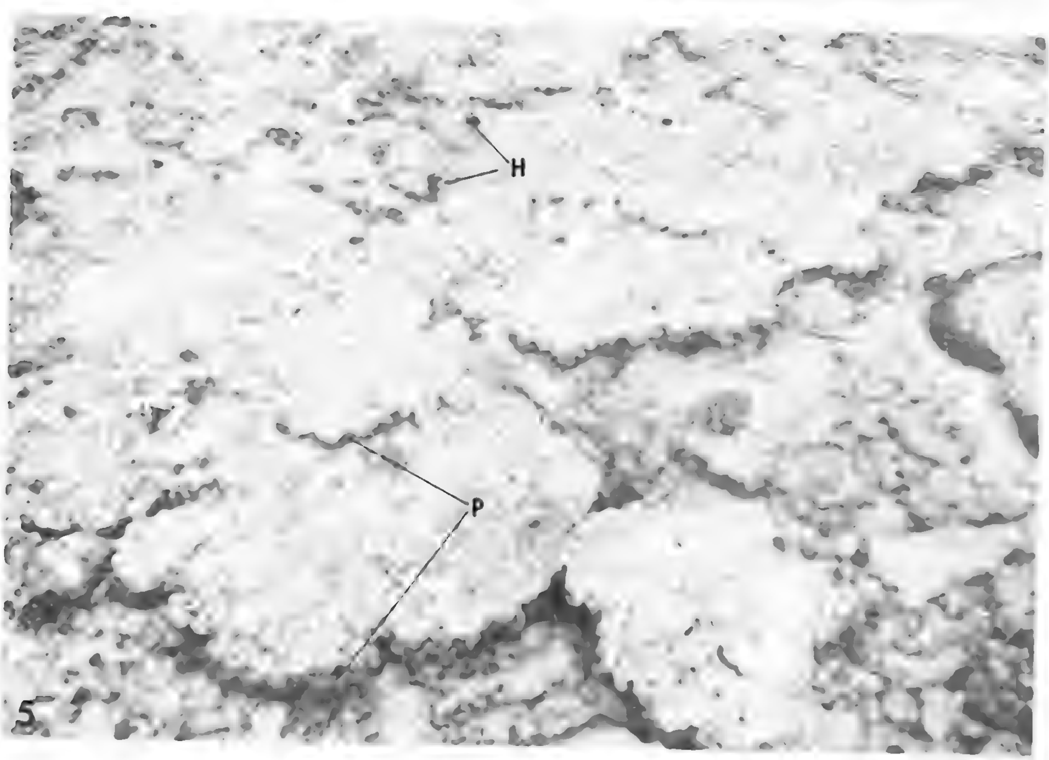

H
P

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Fig. 6. Detail of reef surface with coral rubble and slabs of coral rock in Zone 5b at Pulo Bai, Batu Group, Indonesia (Sta. 101). The cowry Cypraea annulus is very abundant on this substrate. Scale = 0.5 m.

Fig. 7. Outer portion of reef platform at Pulo Bai (Sta. 101), showing abundant living Pocillopora, some Porites, and other corals on rough reef limestone, with sand patches.

Fig. 8. Another portion of outer reef platform at Pulo Bai (Sta. 101), showing thickets of Acropora separated by sand. Photo by Dr. J. W. Nybakken.

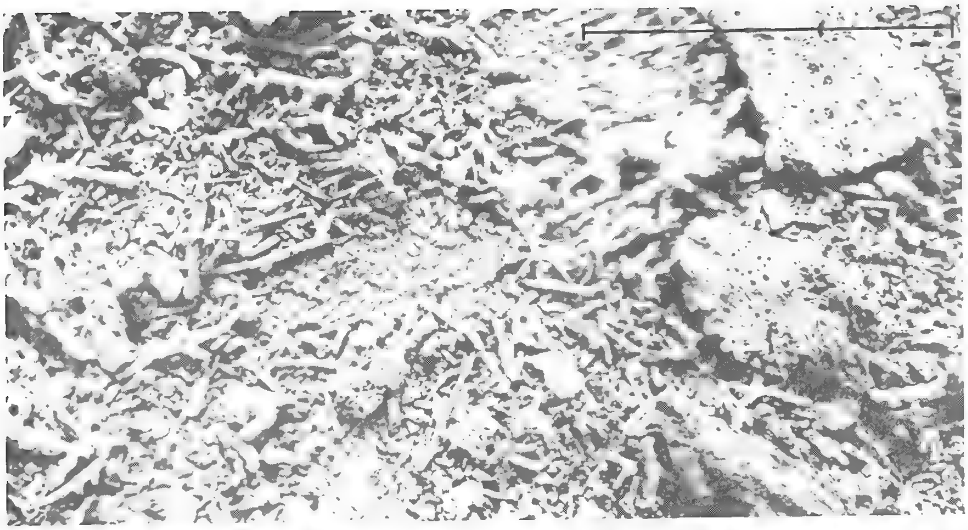

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Fig. 9. Mixed thicket of <u>Acropora</u> and other corals bordered by sand, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

Fig.10. Complex assemblage of corals, including <u>Psammocora</u> and <u>Pocillopora</u>, bordered by sand, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

Fig.11. Complex assemblage of corals including <u>Porites</u>, <u>Montipora</u> and <u>Acropora</u> spp. cemented to rough reef limestone, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

Fig.12. Complex assemblage of low-growing corals, including <u>Acropora</u>, <u>Goniastrea</u>, and <u>Pocillopora</u> cemented to rough reef limestone, outer portion of reef platform at Pulo Bai (Sta. 101). Photo by Dr. J. W. Nybakken.

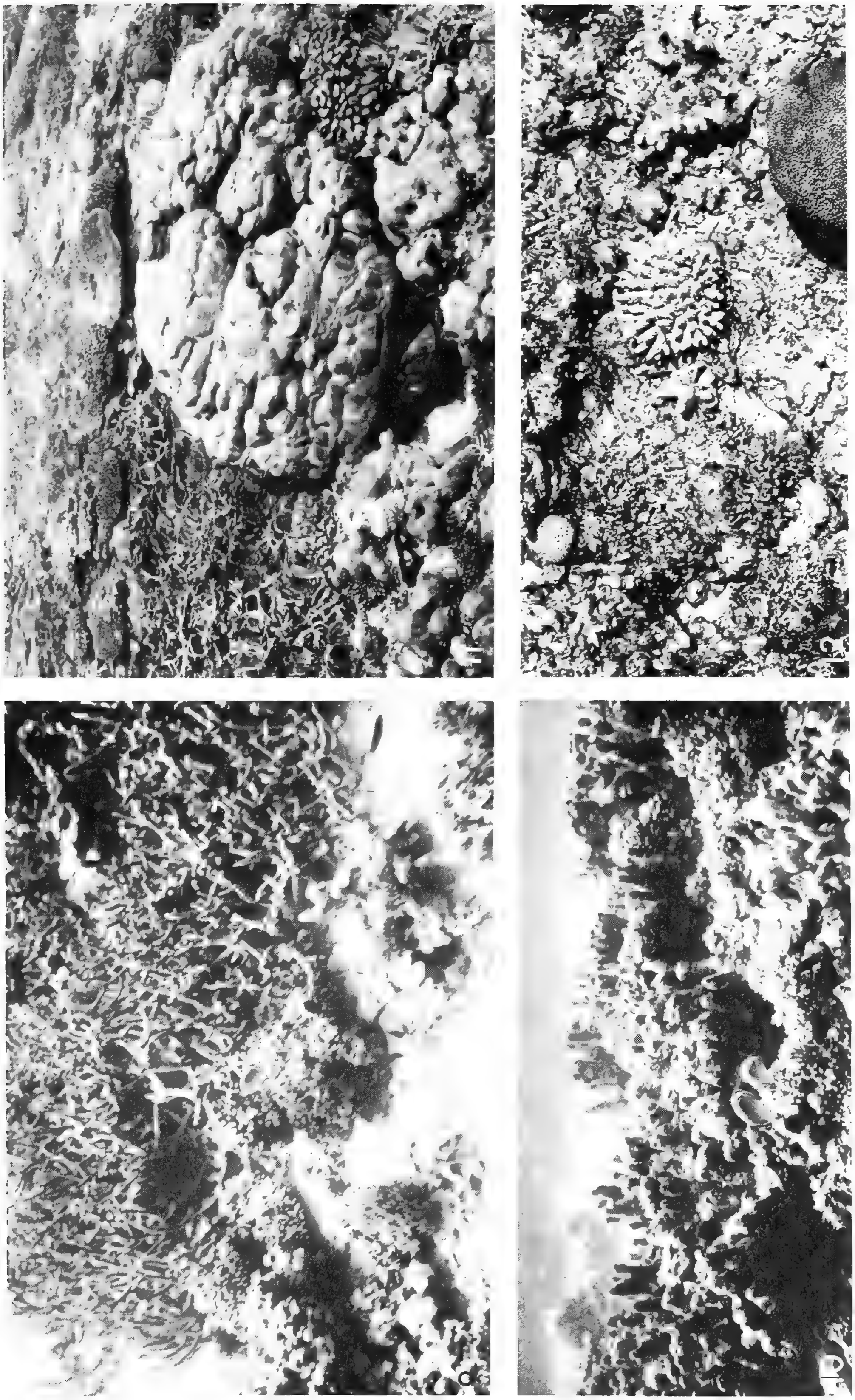

Fig.13. View of island in Veeckens Bay, South Pagi Is., Indonesia (Sta. 105), from the north. South Pagi in right background. Figs. 14-18 show details of shore topography of this island.

Fig.14. Raised reef and detrital limestone bench on south side of island, with narrow, steep beach of sand and coral rubble. Water at about +1.8' level.

Fig.15. Inshore edge of bench and boulder beach on south side of island, showing detrital limestone and mangroves advancing on flat.

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Fig.16. View toward southeast of exposed bench, showing heavy surf and coral boulders lying on flat.

Fig.17. Bench on southwest side of island, showing surge channels and pitted limestone. Foreground is 45-50 m from shore.

Fig.18. Details of relatively unweathered section of pitted zone, showing remains of truncated reef corals. 22 m from shore. The pick is 0.3 m long.

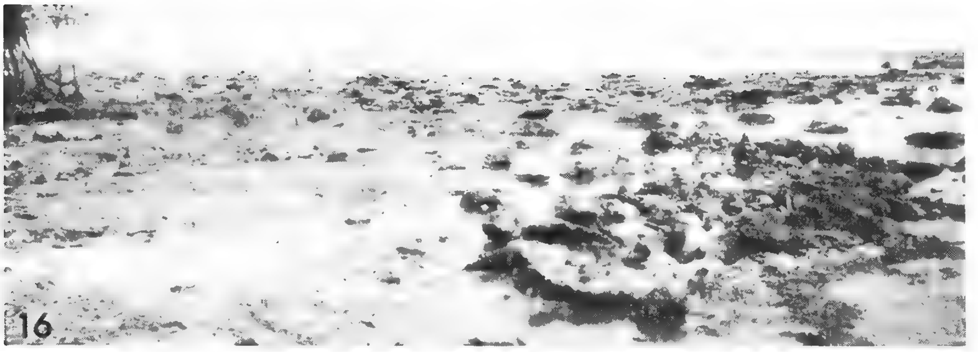

Fig.19. Photograph of Pulo Stupai, Sanding Island, Indonesia (Sta. 108) from the northeast. Sta. 108A is in front of the right side of the island, Sta. 108B, the sand cay at far right. Sanding Island in background.

Fig.20. Map of Sanding Island and associated islets on fringing reef, based on Indonesian Chart 134 and 242.

Figs. 21 and 22. Detail of smooth limestone bench in Zone 2, 85 m from shore, Pulo Stupai (Sta. 108A), showing _Halimeda_ and one _Porites_ head. The lines in Fig. 21 mark a 4 x 4 m quadrat on the transect across the bench.

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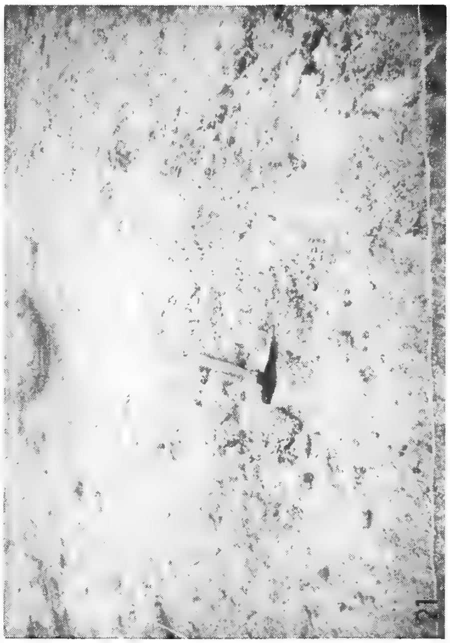

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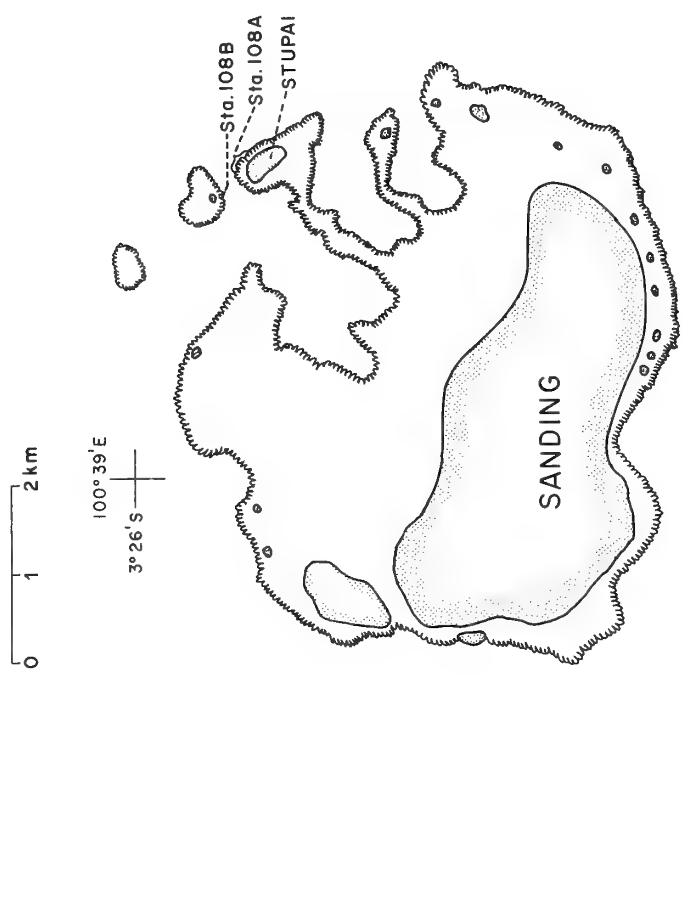

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Figs. 23 and 24. Detail of topographically more complex substrate of rougher reef limestone bench, about half way across the reef platform (about 115 m from shore) at Pulo Stupai (Sta. 108A), showing dead coral boulders, Halimeda, and small sand pockets.

Fig. 25. View along reef from a point 125 m from shore, Pulo Stupai (Sta. 108A). Increasingly complex substrate, with many cobbles and small boulders and abundant Halimeda.

Fig. 26. Seaward reef margin at Pulo Stupai (Sta. 108A), about 165 m from shore, showing abundant Halimeda clumps (H), living Acropora (A), cemented to rough reef limestone veneered by Porolithon (P). There is little loose rubble in this region of breaking waves and heavy surge.


23


24


25


A
H
P
26

ATOLL RESEARCH BULLETIN

No. 141

THE DISTRIBUTION OF SHALLOW-WATER STONY CORALS AT MINICOY ATOLL IN THE INDIAN OCEAN WITH A CHECK-LIST OF SPECIES

by C. S. Gopinadha Pillai

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THE SMITHSONIAN INSTITUTION

Washington, D. C., U. S. A.

February 16, 1971

THE DISTRIBUTION OF SHALLOW-WATER STONY CORALS AT MINICOY ATOLL IN THE INDIAN OCEAN WITH A CHECK-LIST OF SPECIES

by C. S. Gopinadha Pillai**

INTRODUCTION

Hardly anything has been published on the corals and coral reefs of the Laccadive Archipelago since the pioneer work of Gardiner (1900, 1903, 1904, 1905). It was only proper, therefore, that the recent symposium on corals and coral reefs, organised by the Marine Biological Association of India, at Mandapam Camp, review the situation and adopt a resolution emphasising the need for further work on the reef systems of this area as well as on the other little-investigated reefs of the Indian Ocean. The present communication results from the author's observations of the shallow water scleractinians of Minicoy (= Minikoi) Atoll during March-April 1968. A fairly representative collection of reef corals was also assembled. A detailed systematic account of the species collected from the Laccadive Archipelago will be published elsewhere.

THE ATOLL OF MINICOY

Location

The Atoll of Minicoy (Long. 73°E. Lat. 8°17'N. Fig. 1) is situated to the south-west of peninsular India. It is 344 km away from the nearest point in the Indian subcontinent. The Nine Degree channel separates Minicoy from Kalpeni Atoll and Suheli Par, lying respectively to the north-east and north-west; and the Eight Degree channel from Ihavandiffolu (= Ihavandifulu) Atoll of the Maldive Archipelago to the south. Minicoy is situated about 112 km and 192 km from Kalpeni and Ihavandiffolu, the nearest atolls to the north and the south respectively.

Topography

Minicoy Atoll is approximately oval-shaped, elongated in a north-east-southeast direction. The atoll is about 8 km long, with a greatest

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** Present address: Central Marine Fisheries Research Sub-station, Church Landing Road, Ernakulam, Cochin 16, Kerala, India.

width of 4.6 km. The island is about 9.5 km in length, the maximum width being 650 metres (Gardiner, 1900). "Here in Minikoi we have a typically situated island, of an atoll with the reef continuing unbroken at its west end, round which the tide surges with considerable force" (Gardiner, 1903, 32). The villages, with a population of over 5000, are located at the mid-length of the island. The land vegetation is luxuriant and is dominated by coconut trees. *Artocarpus altilis* and *Pandanus* sp. are very common. Recently several garden plants have been introduced from the mainland. The lagoon side of the island is sandy with coral shingle piled up at the northeastern and southwestern ends. The seaward side is mostly rocky with the reef flat subjected to heavy breakers. The height of the island above M.S.L. is about 1.8 metres.

The Lagoon

The lagoon occupies an area of about 10 sq. km. It is generally shallow with shoals rising from the bottom at several places. The depth of the lagoon ranges from 1 to 13 metres. The southern side has a sand flat occupying about half of the lagoon. The infauna of the sand flat consists chiefly of sea-anemones, sipunculids, sea-cucumbers and the enteropneust, *Ptychodera*.

The Reefs

The atoll reef is broken by three channels, viz. Neru-Magu, Kondi-Ma and Weli-Gandola, towards the northeast of Ragandi Islet. The Tori-Gandu Channel is situated at the northeastern extremity of the atoll. The reef extending from Tunda Point has two small islands on it, Wiringili (Small-Pox) and Ragandi. Wiringili is covered with a few coconut trees whereas Ragandi is unvegetated. Ragandi is composed of coral shingle and reef-blocks covered by loose sand. During the monsoon the sea washes over this island, transporting much of the shingle and sand into the lagoon. Between these two islands there is a small channel, the Choru-Magu, constructed by the removal of corals, through which small boats can enter the lagoon at high tides. The reef from Tunda Point to Neru-Magu is exposed at low tide but further east it always remains submerged. The seaward reef from Tunda Point to Kodi Point is always subjected to heavy breakers. The shore between Rocbera Point and Kodi Point is strewn with coral boulders and shingle. The outer reef slopes descend to great depths. For further details of the morphology of the reefs, see the account by Gardiner (1903).

CLIMATE

The climate is typically tropical and is much affected by the warm waters of the Indian Ocean. The mean monthly atmospheric temperature fluctuates between 29.5°C and 31°C with the maximum in April-May and minimum in January-February. Diurnal variation is about 3°C. Relative humidity varies from 72 to 82 in different months. For further details, see the West coast of India Pilot (Ninth Edition, 1950).

The atoll is exposed to both northeast and southwest monsoons. "Heavy storms are common at the commencement of the monsoons. The currents in this region depend mainly on the winds and vary perhaps up to 50 miles per diem" (Gardiner, 1900). The major part of the rainfall is experienced during the S.W. monsoon, in June, July and August. The mean annual rainfall for the period January 1960 to December 1968 is 180.6 cm, with a maximum of 225 cm in 1960 and a minimum of 156 cm in 1966 (Regional daily weather Report, Regional Meteorological Centre, Madras).

DISTRIBUTION OF CORALS

The occurrence and concentration of the various reef corals, both in the lagoon shoals and in the reef proper show notable variation in different parts of the atoll. For descriptive purposes the atoll is here divided into 9 zones (Fig. 2), the demarcation being purely arbitrary. The zones 1-4 are located in the lagoon and 5-9 on the peripheral reef.

Zone 1:

The shore near Tunda Point at the Southwestern end of the atoll is formed of coral shingle. Near the shore there are large raised colonies of *Goniastrea* and *Platygyra*, mostly eroded. At high tide they are partly submerged. The bottom of the lagoon in this area is sandy with occasional patches of corals. *Porites somaliensis* and *P. solida* form flat-topped colonies half to one metre in diameter. Interspersed with *Porites* there are colonies of *Acropora intermedia* with comparatively stunted branches because of the shallowness of the water at low tides. Many of the colonies are dead. *Leptastrea transversa*, *Favia pallida*, *Platygyra lamellina* and rarely *Psammocora haimeana* are seen attached to the *Porites*. This is the only place at which I could see *Euphyllia glabrescens* in Minicoy and the genus appears to have a restricted distribution here. The colonies are 15 to 25 cm in spread and the polyps of this species are found partly expanded during day with their tentacles hanging down. Stomatopods and sea-cucumbers are plentiful among dead and living corals, but there is an apparent paucity of reef-dwelling fishes as compared to the other parts of the lagoon. This may probably be due to the comparatively lesser growth of corals in this zone.

Zone 2:

The central part of the sand-flat shows an exceptionally rich growth of corals. The lagoon bottom possesses several shoals at a depth of 1 to 2 metres at low tide. The spaces between the shoals are sandy with a large number of molluscan shells and dead coral fragments. The reef-dwelling ichthyofauna of this zone is rich and varied. Both massive and ramose corals are flourishing in this zone. *Diploastrea heliopora* and *Porites* spp. among the former attain considerable size and colonies may measure more or less a metre in diameter. *Favia*

pallida, Favites abdiata, Goniastrea retiformis, Platygyra lamellina, Leptoria phrygia, Symphyllia recta and Lobophyllia corymbosa also occur in fair numbers on certain shoals. But the dominant corals of this zone are the various species of Acropora. A. pharaonis forma arabica, A. intermedia, A. formosa, A. echinata, A. rambleri, A. abrotanoides and A. palifera are in plenty. Certain shoals are full of these branching species with little representation of massive types. Larger colonies of A. pharaonis measure about 1.5 metres in height. Acropora palifera could be seen within the lagoon only in this zone though it appears to be common towards the outer side of the lagoon reef. The paucity of the massive forms where ramose ones dominate is an interesting feature noticed here. This may be due to the crowding out of the slower growing massive forms by the faster growing ramose species (Mayer, 1918). Rarely Millepora tenera and Pocillopora damicornis are found mixed with others.

Zone 3:

This zone is identified at the north-eastern side of the atoll, about 2 km south-west of Kodi Point near the shore, where there is a well developed shoal about 100 metres away from the shore. This shoal is the largest observed in the lagoon and is almost like a miniature "fringing reef" within the lagoon. It is about 600 metres long (measured along the shore) and 40 to 60 metres wide at different parts. It is mostly made up of large colonies of Goniastrea retiformis, the top of adjacent ones being fused into an almost level platform. The lagoon near shore is hardly a metre and a half deep at high tide but outward to the shoal the depth increases to three to four metres. Diploastrea heliopora, Lobophyllia corymbosa, Platygyra lamellina and Leptoria phrygia form large colonies about one metre in diameter on the margins of the Goniastrea retiformis. Porites is not dominant in this zone. Favia pallida, Favites abdiata etc. are also met with but never in abundance. There is a paucity of ramose forms though occasionally Pocillopora damicornis, Psammocora contigua and Acropora spp. are met with. Towards the outer side of the shoal large colonies of Psammocora exesa are seen. It appears that this species has only a restricted distribution in the lagoon. The area east of this, extending to Kodi Point, could not be surveyed.

Zone 4:

The northeastern side of the lagoon towards the east of Kondi-Ma (Kandi-Ma) channel possesses certain shoals at a depth of 4 to 6 metres. The coral growth is not so dense or diverse as it is in the central part of the lagoon. The conspicuous corals are the various species of Acropora. A. efflorescens, A. formosa and A. hyacinthus are fairly common. Galaxea fascicularis and Goniopora sp. cf. minor were also collected along with F. scutaria and other massive faviids.

Zone 5:

The lagoon reef extending from Tunda Point to Wiringili Island has a well developed boulder zone and a flat that is exposed at low

water. On the reef flat the dominant corals are Pocillopora damicornis with a few small colonies of Porites. Acropora monticulosa, Leptastrea transversa, Favia pallida and fairly large colonies of Millepora platyphyllia were also seen.

Zone 6:

The reef between Wiringili and Ragandi shows three well defined zones: the fissure, reef flat, and boulder zone (Gardiner, 1903). The flat is about 50 metres wide separated by the boulder zone from the lagoon. The boulder zone is about 30 metres in width with dead loose colonies of Favia, Platygyra, Goniastrea and Porites. On account of the extremely rough weather at the time of the author's visit, a detailed survey of the flat and other side of the reef was not possible. The inner reef, to the boulder zone, up to about half a kilometer east of the Choru-Magu Channel, is full of Heliopora coerulea. Occasionally Pocillopora damicornis, P. ligulata, Acropora indica and Merulana ampliata and Porites spp. are seen. Fungia scutaria is seen in fair numbers.

Zone 7:

From the limit of the Heliopora zone up to the Neru-Magu Channel there is a notable change in the composition of the reef-building corals. Porites solida, P. lutea and P. somaliensis replace Heliopora of Zone 6. Fungia scutaria shows a tendency to dwindle in numbers. A few tufted Acropora and Pocillopora damicornis are also met with. In zones 6 and 7 the ramose corals are rare.

Zone 8:

The reef from Neru-Magu to Kodi Point always remains submerged. The growth of corals is not so luxuriant as in the southwestern sector of the reef. Both ramose and massive corals are met with but none of the genera is abundant.

Zone 9:

The seaward reef flat. The reef flat from the Tunda Point to the Kodi Point facing the open ocean side was investigated at certain areas by wading through to a distance of 50 to 60 metres away from the shore. The present account has not much to add to the excellent description of Gardiner (1903). The shores especially to the Mau-Ramu (Mou-Rambu) Point and at Ko-vari Bay have a good amount of shingle mostly of Pocillopora eydouxi, P. verrucosa, Stylophora mordax and Acropora spp. The reef flat possesses Pocillopora damicornis, Acropora monticulosa, Favia pallida, Leptastrea, Platygyra, Millepora platyphyllia, etc. Gardiner (1903) mentions the occurrence of Pavonia varians, Psammocora contigua and Porites palmata along with three or four facies of Acropora at Teverattu (Teveratu) Point. The reef flat off the Light House is poor in coral growth. According to Gardiner (1903) "an encrusting Montipora alone attains any magnitude, although most of the genera found at Teveratu may be represented". However, the present author could not locate any species of Montipora throughout Minicoy.

Table 1. Representation of common genera of reef corals of Minicoy in lagoon and on reef flat

Genus	Lagoon	Reef flat
Acropora	A	C
Diploastrea	A	R
Euphyllia	L	*
Favia	C	C
Favites	C	C
Fungia	L	C
Goniastrea	A	R
Goniopora	S	*
Leptastrea	C	C
Leptoria	C	R
Lobophyllia	A	*
Merulina	*	S
Platygyra	C	C
Pocillopora	C	C
Porites	C	A
Psammocora	L	R
Symphyllia	R	R

A-Abundant. C-Common. R-Rare. L-Rare and localised. S-Known by a single colony. *Not recorded but may occur.

COMPOSITION OF THE CORAL FAUNA

The hermatypic scleractinian corals of Minicoy so far as known at present include 70 species in 26 genera. These records are mostly from the shallow waters. Several common Indo-Pacific genera and species of stony corals are yet to be recorded from Minicoy, these include Cyphastrea, Echinopora, Turbinaria and several fungiids. The foliaceous corals such as Echinopora lamellosa and Montipora foliosa, which are common in the shallow waters of Palk Bay and Gulf of Mannar around Mandapam (Pillai, 1967) and on the slopes of Addu Atoll (Stoddart et al., 1966) are not yet recorded from Minicoy. A careful search was made for dead and washed ashore pieces of them among the shingle on the shore but without success. Pocillopora verrucosa, P. eydouxi and Stylophora mordax, all of which are found in plenty in the shingle, could not be seen either on the lagoon shoal or on the reef flat investigated. They are probably found on the reef slopes of Minicoy. Another interesting feature is the paucity of Montipora. The only record of this genus from Minicoy is that of Gardiner (1903), who mentioned the occurrence of an encrusting

species on the reef flat off the Light House area. Future investigations in the deeper waters of Minicoy will certainly modify the faunal list given below.

Check-list of species

Phylum COELENTERATA
Subphylum CNIDARIA
Class ANTHOZOA
Subclass ZOANTHARIA
Order *Scleractinia*
(Classification after Wells, 1956)
Suborder *Astrocoeniina*
Family Thamnasteriidae

1. *Psammocora contigua* (Esper), 1797.
2.* *P.* (*Stephanaria*) *exesa* Dana, 1846.
3.* *P.* (*Plesioseris*) *haimeana* Milne-Edwards and Haime, 1851.

Family Pocilloporidae

4.* *Stylophora mordax* Dana, 1846.
5. *Pocillopora damicornis* (Linnaeus), 1758.
6.* *P. verrucosa* (Ellis and Solander), 1786.
7.* *P. ligulata* Dana, 1846.
8.* *P. eydouxi* Milne-Edwards and Haime, 1860.

Family Acroporidae

9.* *Acropora abrotanoides* (Lamarck), 1816.
10.* *A. conferta* (Quelch), 1886.
11.* *A. corymbosa* (Lamarck), 1816.
12.* *A. echinata* (Dana), 1816.
13.* *A. efflorescens* (Dana), 1846.
14.* *A. formosa* (Dana), 1846.
15.* *A. forskali* (Ehrenberg), 1836.
16.* *A. haimei* (Milne-Edwards and Haime), 1860.
17.* *A. hemprichi* (Ehrenberg), 1834.
18.* *A. humilis* (Dana), 1846.
19.* *A. hyacinthus* (Dana), 1846.
20.* *A. indica* (Brook), 1893.
21.* *A. intermedia* (Brook), 1893.
22.* *A. monticulosa* (Bruggemann), 1879.
23.* *A. palifera* (Lamarck), 1816.
24.* *A. pharaonis* forma *arabica* (Brook), 1893.
25.* *A. rambleri* (Basset-Smith), 1890.
26.* *A. reticulata* (Brook), 1892.
27.* *A. squarrosa* (Ehrenberg), 1834.
28. *Acropora* sp.
29.** *Montipora* sp.

* New records from Minicoy.
** Not collected during the present study.

Suborder Fungiina
Family Agariciidae

30. Pavona maldivensis (Gardiner), 1905.
31. P. varians Verrill, 1864.

Family Fungiidae

32.* Cycloseris sp.cf. somervilli (Gardiner), 1909.
33. Fungia (Danofungia) danai Milne-Edwards and Haime, 1851.
34. F. (Fungia) fungites (Linnaeus), 1758.
35. F. (Pleuractis) scutaria Lamarck, 1801.
36. Podabacia crustacea (Pallas), 1766.

Family Poritidae

37.* Goniopora sp.cf. minor Crossland, 1952.
38.* G. stokesi Milne-Edwards and Haime, 1851.
39.* Porites andrewsi Vaughan, 1918.
40.* P. lutea Milne-Edwards and Haime, 1851.
41.* P. minicoiensis Pillai
42.**P. palmata Dana, 1846.
43.* P. solida (Forskål), 1775.
44.* P. somaliensis Gravier, 1910.

Suborder Faviina
Superfamily Faviicae
Family Faviidae
Subfamily Faviinae

45.**Plesiastrea versipora (Lamarck), 1816.
46. Favia favus (Forskål), 1834.
47. F. pallida (Dana), 1846.
48. F. speciosa (Dana), 1846.
49. Favites abdiata (Ellis and Solander), 1786.
50. F. ehrenbergi (Klunzinger), 1879.
51. F. halicora (Ehrenberg), 1834.
52. F. melicerum (Ehrenberg), 1834.
53. F. pentagona (Esper), 1794.
54.**Goniastrea hombroni (Rousseau), 1854.
55. G. retiformis (Lamarck), 1816.
56. Platygyra lamellina (Ehrenberg), 1834.
57. Leptoria phrygia (Ellis and Solander), 1786.
58.**Hydnophora microconos (Lamarck), 1816.

Subfamily Montastreinae

59. Diploastrea heliopora (Lamarck), 1816.
60. Leptastrea purpurea (Lamarck), 1816.
61.**L. transversa Klunzinger, 1879.
62.**L. bottae (Milne-Edwards and Haime), 1849.

Family Oculinidae
Subfamily Galaxeinae

63.* Galaxea fascicularis (Linnaeus), 1759.
64.**G. hexagonalis (Milne-Edwards and Haime), 1848.

Family Merulinidae

65.* Merulina ampliata (Ellis and Solander), 1786.

Family Mussidae

66.**Acanthastrea echinata (Dana), 1846.
67. Symphyllia radians Milne-Edwards and Haime, 1849.
68. S. recta Dana, 1846.
69.* Lobophyllia corymbosa (Forskål), 1775.

Suborder Caryophylliina
Family Caryophylliidae
Subfamily Eusmiliinae

70. Euphyllia glabrescens (Chamisso and Eysenhardt), 1821.

Subclass ALCYONARIA
Order Coenothecalia
Family Helioporidae

1. Heliopora coerulea (Pallas), 1766.

Class HYDROZOA
Order Milleporina
Family Milleporidae

1. Millepora platyphyllia Hemprich and Ehrenberg, 1834.
2. M. dichotoma (Forskål), 1775.
3. M. tenera Boschma, 1949.

ACKNOWLEDGEMENTS

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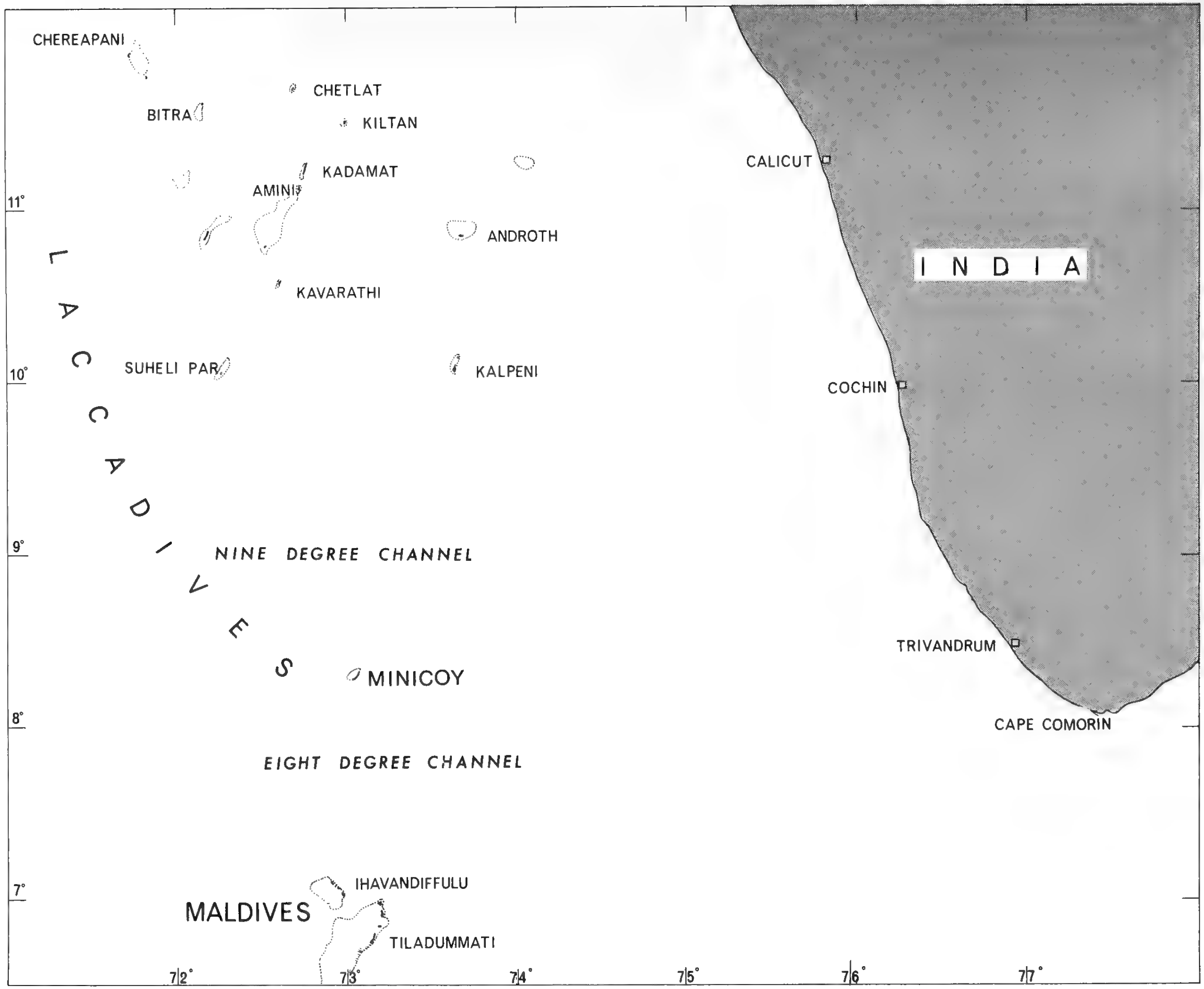

Fig. 1. Location of Minicoy Atoll.

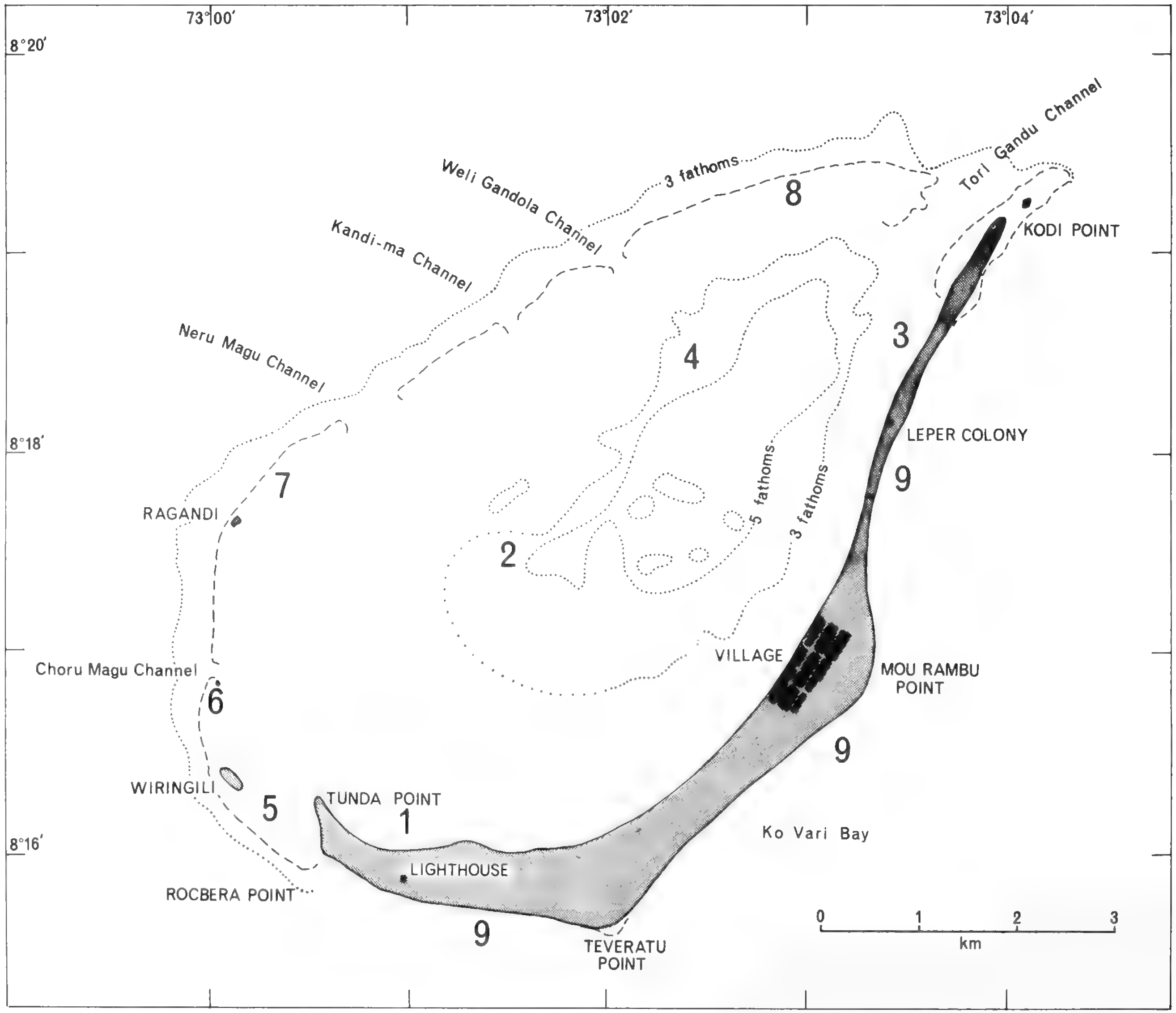

Fig. 2. Minicoy, lagoon and reef zones described (1-9).

ATOLL RESEARCH BULLETIN

No. 142

THE UNINHABITED CAYS OF THE CAPRICORN GROUP, GREAT BARRIER REEF, AUSTRALIA

by S. B. Domm

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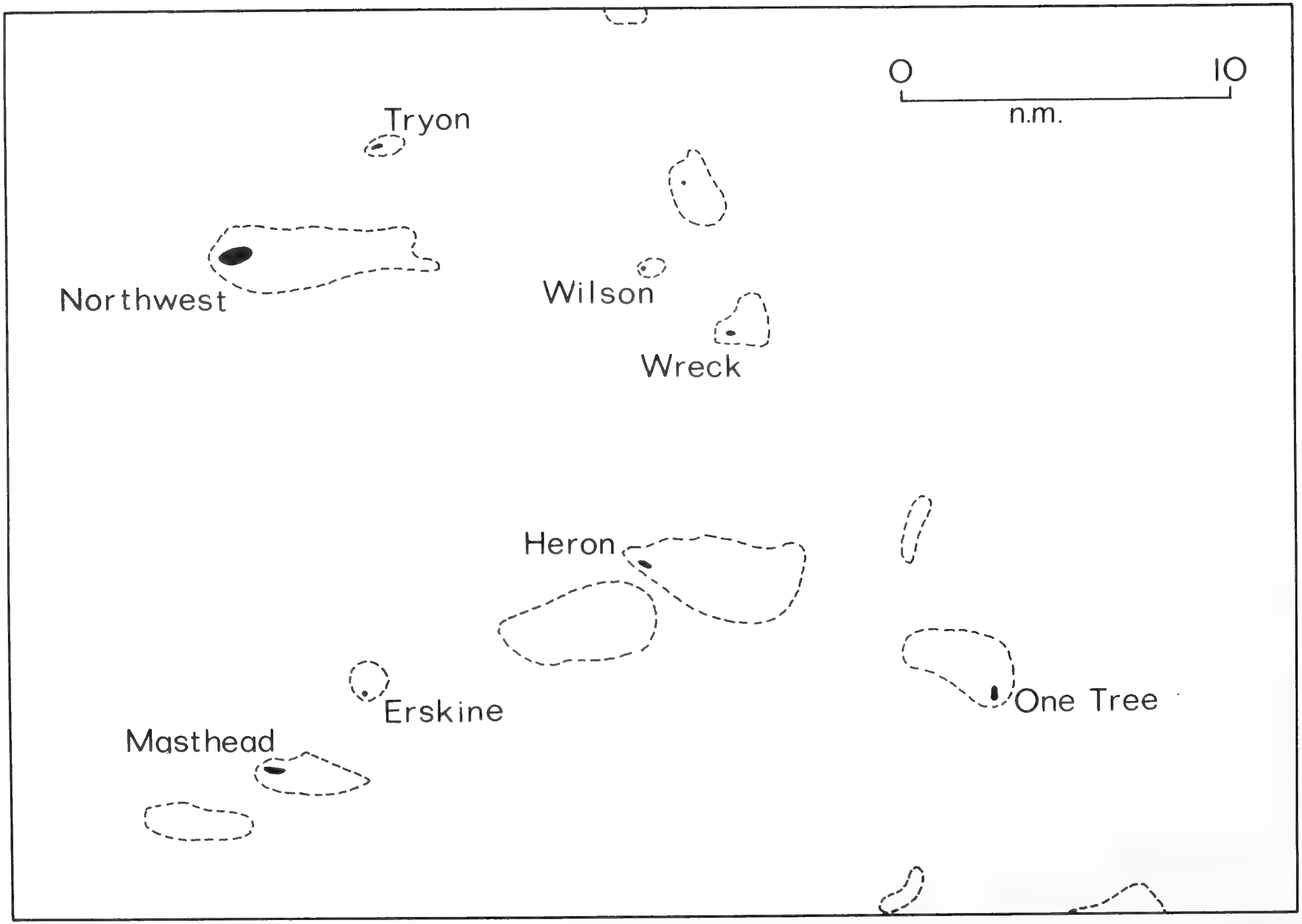

Fig. 1. Capricorn Group

THE UNINHABITED CAYS OF THE CAPRICORN GROUP, GREAT BARRIER REEF, AUSTRALIA

by S. B. Domm

INTRODUCTION

The islands and reefs comprising the Capricorn Group (Fig. 1) lie between 30 and 50 miles out from the port of Gladstone on the coast of Queensland, Australia. This area is near the southern end of the Great Barrier Reef (better called Reefs) of Australia and consists of nine coral cays or islands, two of which are inhabited (Heron Island and the lighthouse at North Reef). There are also four reefs having no vegetated cays on them, however these may contain sand or coarse rubble banks that are usually awash at high tide. Broomfield Reef has a small sand bank on its lee which appears to be growing in size and even at high tide rises about a foot above the water. [An early and very interesting, though incomplete, description may be found in the first chapter of Jukes 1847—Eds.].

Heron Island is one of the larger islands of the Capricorn Group and because a tourist resort and a biological research station (operated by the Great Barrier Reef Committee) are located on it, it is the site of considerable activity. For the past two and a half years the author has worked at the Heron Island Research Station and every opportunity has been taken to visit the other islands in this region.

Now is a good time for a general survey of this group of islands to be made, each year more people visit them as the romance of visiting or living on a coral island is ever alive. It is important to know what effect man is having on these islands in order to intelligently conserve and maintain them in their natural state. They belong to the future as well as to the present.

The nine islands of the Capricorn Group all lie in an area about 30 miles square with Heron Island approximately in the center. All of the islands are situated on reefs which rise from a submarine platform. Nowhere in this area does the depth of water exceed about 35 fathoms and around most of the islands it is much shallower. The platform extends to about 18 miles east of Heron Island where the 100-fathom contour can be taken as the seaward margin.

Since Heron Island is the focal point for all activity in this region, distances and direction will be taken from it. All of the islands of the Capricorn Group are of the type termed "cays" in that they were formed from wave transported material which has now become

stabilized by vegetation and beachrock. In discussing the different islands I am only concerning myself with the major trees, however the flora includes also many species of herbs, shrubs and grasses (see references). The major trees are:

Tournefortia argentea
Scaevola taccada
Casuarina equisetifolia
Pisonia grandis
Pandanus tectorius

On all of the larger sand islands these trees are characteristically found growing in zones. On the smaller islands these zones become less apparent due to the effect of the wind and probably moisture [and salinity ? Ed.]. Figure 2 is a diagrammatic sketch of a typical island of the larger type showing the usual zones of dominant trees.

All of the sand islands of the Capricorn Group are used extensively by the Green Turtle (*Chelonia mydas*) and the Loggerhead Turtle (*Caretta caretta*) to lay their eggs. The nesting turtles often do much damage to the marginal vegetation by digging up the area.

The Capricorn Group and the adjacent but more southerly Bunker Group together form a distinct province with many similar features, but most important of all is that they are the southern terminus of a vast complex of reefs and islands extending for over a 1,000 miles--the Great Barrier Reef of Australia.

BIRDS OF THE CAPRICORN GROUP

Wedge-tailed Shearwater or Mutton Bird (*Puffinus pacificus*)
Reef Heron (*Egretta sacra*)
Silver Gull (*Larus novaehollandiae*)
Brown or Common Noddy (*Anous stolidus*)
Black or White-capped, Noddy (*Anous minutus*)
Crested Tern (*Sterna bergii*)
Lesser Crested Tern (*Sterna bengalensis*)
Black-Naped Tern (*Sterna sumatrana*)
Bridled Tern (*Sterna anaethetus*)
Roseate Tern (*Sterna dougallii*)
Fairy Tern (*Sterna nereis*)
Black Oystercatcher (*Haematopus fuliginosus*)
Pied Oystercatcher (*Haematopus ostralegus*)
Little Pied Cormorant (*Phalacrocorax melanoleucos*)
Bar-Tailed Godwit (*Limosa lapponica*)
Eastern Curlew (*Numenius madagascariensis*)
Lesser Knot (*Calidris canutus*)
Turnstone (*Arenaria interpres*)
Mongolian Plover (*Charadrius mongolus*)

Golden Plover (Pluvialis dominica)
White-Breasted Sea Eagle (Haliaetus leucogaster)
Brown Booby, or Gannet (Sula leucogaster)
Lesser Frigate Bird (Fregata ariel)
White-eye, or Silver-eye (Zosterops lateralis)
Sacred Kingfisher (Halcyon sancta)
Banded Rail (Rallus philippensis)
Bar-Shouldered Dove (Geopelia humeralis)

This list is not comprehensive since various species of migratory waders and others may pass through this area unnoticed by the author. Furthermore, birds are occasionally seen from the mainland but these seldom if ever remain in permanent residence on the island (Northwest Island may be an exception).

DESCRIPTION OF CAYS

Northwest Island

Northwest Island (Fig. 3, Plates 1-2) is the largest of the Capricorn Group and is located about 18 miles to the northwest of Heron Island. It is composed of sand and situated on the western end of a long reef which has no lagoon; the island is aligned approximately southwest by northeast. The major trees are found in the zones characteristic of this region with Tournefortia and Scaevola plus Casuarina and scattered Pandanus growing along the perimeter and enclosing a very extensive forest of Pisonia. There is a grove of Casuarina on the western end of the island.

The only exposure of beachrock is on the northeast corner and here much of the sand is being washed away from behind the beachrock. For so large an island there is very little beachrock.

On the southwest corner active erosion is taking place and here one finds many uprooted trees (mostly Casuarina) and some cliffing of the beach margin. There is evidence of erosion on other parts of the island.

Northwest supports a very large population of White-capped (Black) Noddies, and Mutton Birds (Shearwaters) and many different types of waders can be found here. Also of interest is that this island is often the home of various types of mainland birds, the more obvious being: Currawong, Peewee, White-Faced Heron and Cuckoo-Shrike.

Introduced chickens appear to be increasing in number and there are at least several cats on the island. Because it is a large island on a long reef, Northwest provides a very good lee in southeasterly weather, also, since it possesses two sheds whose roof drainage provides at least some fresh water it is popular with visitors and is more often inhabited than the other islands.

Masthead Island

Masthead Island (Fig. 4, Plates 3-8) is the second largest uninhabited island of the Capricorn Group, about 12 miles southwest of Heron Island. It is somewhat protected by the presence of Pomaise Reef on the southwest and the much smaller Erskine Island and Reef 3 miles to the northeast. Masthead is a long rather narrow island aligned approximately east-west and is situated on the western end of a long narrow reef which has no lagoon.

Masthead is covered by a dense vegetation the major trees of which are zoned in the characteristic manner of this region. The interior contains a mature forest of *Pisonia* while the perimeter is colonized by the usual *Tournefortia* and *Scaevola* with scattered *Pandanus*. *Casuarina* are found in well-developed groves on the ends of the island and about halfway along the northern side. This last extensive grove is remarkable for the straight line of its trees and may have once continued further but has been eroded back as the whole island appears to have shifted its western end to the south; further evidence of this is found in several isolated outcrops of old beachrock now found a distance from the beach.

Beachrock is well developed along the southeast (windward) corner where also some erosion appears to be taking place. The lee of this island seems to be building up as low dunes are being colonized by grasses.

An interesting feature of Masthead is the presence of a type of cactus or prickly-pear which appears to be gradually gaining a foothold on the island and probably originated from seedlings or plants washed ashore. If such a plant as this continues to spread it could drastically upset the ecology of the island.

The usual sea birds frequent this island and I have seen hundreds of White-Capped Noddies and Mutton Birds, nesting Silver Gulls, Bridled Terns and Crested Terns.

The western *Casuarina* grove is a favored spot with campers.

Tryon Island

Tryon Island (Fig. 5, Plate 9) is located about 15 miles to the northwest of Heron Island and about 5 miles from Northwest Island. It is rather small, fairly narrow and aligned about 65 degrees. Tryon is composed entirely of sand and is rather flat with a slight ridge along the western side.

It is covered by a dense vegetation in which the major trees assume the zones found on most of the other islands. The central *Pisonia* forest is surrounded by a zone of *Tournefortia* and *Scaevola* with

scattered Pandanus and Casuarina. On the western tip there is a grove of Casuarina. There is a very large fig tree on this island, also a small palm. Otherwise the vegetation, as on most of the other islands, includes a few minor trees and bushes, with some grass.

There are several outcrops of beachrock, with one extensive development with a strike running out from the angle of the existing beach. These beachrock "spurs" are always good evidence that the margins of the island have migrated away, the sand being washed from here to be deposited elsewhere. On Tryon Island there is an outcrop of what I take to be fossil beachrock high up on the beach in the vegetation. If this rock is *in situ*, it represents beachrock that was formed when sea-level was slightly higher than at present, since beachrock at present only seems to form at the intertidal zone of the beach.

There appears to be little present erosion taking place on Tryon Island and this may be due to its relatively protected position. Northwest Reef and the sand train which continues almost to Wilson Island would certainly influence the force of the seas reaching Tryon Island during southeasterly weather.

The effect of visitors on this island doesn't appear to be very extensive, although campers on the nearby Northwest Island may frequently come across.

Wreck Island

Wreck Island (Fig. 6, Plates 10-11) lies about 8 miles NNE of Heron Island and is a small narrow island aligned approximately 240 degrees magnetic. Wreck Island was the site of a bore put down to explore the strata underlying these reefs in 1950. It is composed entirely of sand and there is well developed beachrock along the southern (windward) side extending for about half the length of the island; much of this beachrock is now being eroded away.

The surface of the island is rather uneven in that along most of the southern margin (central area) there is a high ridge (about 20 feet above the beach). This ridge forms a kind of "backbone" to the whole island and is covered by vegetation, indeed it is in the lee of this ridge that one finds the small but well developed Pisonia forest which provides a delightful camping spot. On a small island like this some sort of protection from the prevailing southeast winds and occasional storms is necessary if the rather fragile Pisonia trees are to attain anything approaching their mature height. The ridge itself is densely covered by bushes and especially along the margin facing the beach is found the zone of Tournefortia and Scaevola trees. On the ends of the island there are small groves of Casuarina, that on the northeast tip being especially well developed. Pandanus are found scattered about the entire surface of the island.

On the northwest side (lee) of the island there is a cleared area across the reef flat leading out from about the middle of the island to the reef margin. This was probably cleared during the time when the bore was sunk and provides an easy approach to the island in southeasterly weather when the depth of water is uncertain.

Some erosion is taking place along the margins of this island and the sand bars extending from its ends are constantly shifting.

Due to an unfortunate infestation by rats I expected the bird population to be adversly affected. However most of the birds characteristic of this area can be seen here at one time or another and the island seems to support quite a large Silver Gull population. An interesting point is that few White-Capped Noddies nest on Wreck Island while on Heron Island only a short distance away they nest in thousands. Wreck Island appears to be the favored nesting site for the Loggerhead turtle.

Unfortunately the effect of visitors has been such that much of the island's pristine character is now gone. There is an abundance of rusting tins of various types (including an old water tank) scattered about, and trees are being cut down in the camping area.

Wilson Island

Wilson Island (Fig. 7, Plates 12-15) is about 9 miles north of Heron Island and 3 miles from Wreck Island, and is located on the western side of a very small reef. Wilson Island has several interesting features; it is made up of a mixture of sand and coarse rubble, and it is a relatively large island in comparison to its reef, which indicates that the size of the reef is not a completely limiting factor in determining the size of a cay.

The distribution of the major trees is rather different on Wilson Island than on the other sandy islands. The dominant trees are *Pandanus* which forms an extensive grove along the eastern side and *Casuarina* which is abundant along the northwest and southwest sides. A cyclone several years ago did much damage to the *Pandanus* and now many are uprooted or have their tops blown off and are dead, presenting a rather bleak appearance. Wilson is rather open in that the vegetation for the greater part is scattered and there is no *Pisonia* forest, instead the *Pisonia* occur as scattered trees. *Tournefortia* and *Scaevola* are also present.

Very well developed beachrock encircles half of the island from the southeast to the northwest, i.e. on the windward side. Much of this beachrock has been broken up by wave action and lies high on the beach in great slabs. Wilson Reef is not large enough to protect the cay from the force of storm waves during a high tide, although some protection is gained from Wreck Reef and also the nearby Bloomfield Reef (2 miles to the northeast).

Wilson Island is very easy to approach as the cay is almost adjacent to the lowest part of the reef and even during low water there is sufficient depth over the reef for a small boat to be brought in to the beach. This makes Wilson a popular island for guests from the Heron Island Hotel to visit and therefore it must be the most frequented of the uninhabited islands of the Capricorn Group. Evidence of these visits can be found in the crude tables and small rubbish tip which detract from its beauty. It does not appear to support a very large bird population.

One Tree Island

One Tree Island (Fig. 8, Plates 16-20) is about 12 miles east-southeast from Heron Island and is the most exposed of the islands of the Capricorn Group. It has many unique features: it is the only island that is found on the eastern end of its reef, all the rest are found on the western end (lee); another unique feature (for the Capricorn Group) is that One Tree is constructed of coral rubble, there is practically no sand on it. The reef of One Tree appears to be slightly higher than that of others in the group and also contains a deep and well developed lagoon. Towards the center of the island there is a small pond of brackish water.

The zonation of dominant trees found on most of the other islands is absent from One Tree. Here the trees consist of scattered *Tournefortia* and *Scaevola*, either as single trees or in small clumps, found along the perimeter. There are also several small groves of rather wind-blown *Pisonia* and some well developed *Pandanus*. Between these scattered groves there is a thick vegetation of low bushes.

The shape of One Tree is a manifestation of the forces acting upon it; it is rounded towards the southeast and the lee is drawn out into two "horns" pointing down wind. Along the perimeter of One Tree are very high ridges of rubble formed by storm waves, and indeed the island seems to consist of a series of ridges. The coralline rubble is of a very coarse nature and consists of fragments of coral and reef rock.

One Tree appears to support a rich and varied bird fauna and especially the open area next to the pond is, during the nesting season for the Terns (spring), the scene of much activity. Crested, Lesser Crested, Roseate and Black-Naped Terns all vie with each other for nesting sites around the pond while Bridled Terns rear their young among the rubble along the margin of the island just above the high tide mark.

One Tree Island has in the past few years been the location for considerable scientific work and various studies are currently being carried out there, yet I am always impressed by the lack of evidence of these visits. There is a kind of lonely beauty about this rugged, rather desolate island that is different from all the other islands of the Capricorn Group.

Erskine Island

Erskine Island (Fig. 9, Plates 21-24) is the smallest of the Capricorn Group and is located about 7.5 miles southwest of Heron on the northwest side of a small reef. Erskine is composed entirely of sand and appears rather high for its small size. It may receive some protection from the nearby Wistari and Masthead reefs but this is doubtful since the southeast is unobstructed and the only effect of these two reefs may be to channel the tidal stream in such a way that it flows past Erskine at an increased rate.

The pattern of vegetation (major trees) is more simple here than on most of the other sand islands because Erskine is so small that it is not sufficiently protected from the wind to enable a central *Pisonia* forest to grow. Here one finds a well developed fringe vegetation of *Tournefortia* and *Scaevola* with many trees in the center of the island. On the lee side (north) of the island there is a small grove of very stunted and wind-pruned *Pisonia* seldom exceeding 10 feet in height. There are no *Pandanus* or *Casuarina* trees on Erskine.

Beachrock appears to have been very well developed in the past on the northern side (lee) but now it lies piled up in great slabs high on the beach. On so small a reef the island is rather vulnerable and subject to intense wave action during a strong wind with a high spring tide, yet very little active erosion appears to be taking place on Erskine.

Few White-Capped Noddies or Mutton Birds use this island for nesting nor does it appear to be used as extensively by nesting turtles as the other sand islands.

DISCUSSION

From the above "Descriptions" it can be seen that the islands of the Capricorn Group, with the exception of One Tree, are all very similar: in their composition (sand), in their location of the reef (lee) and for the larger ones in the zonation of their major trees. Even though in reality they are nothing more than permanent vegetated sand banks they are, under the present set of conditions, stable features, stable in that they exist in a state of equilibrium with the forces acting on them. Wind-driven waves during a spring high tide will very often cause erosion on the windward side; the sand that is removed may be lost to the island or merely transported to the lee sandspit found on many of the islands. Exposed roots, dead and uprooted trees, and cliffed beach margins attest to the fact that the foregoing conditions are not infrequent. The margins of most islands tend to shift position, being constantly molded by the prevailing weather conditions. It is possible for a whole island to slowly migrate to a slightly different position on its reef and proof of this can sometimes

be found in isolated outcrops of beachrock. These outcrops have a strike that is quite different from the line of the existing beach, all of the sand having been washed away from behind the line of rock which extends out onto the reef flat at an angle to the beach. During high tides erosion begins to remove the rocks and sometimes all one can see are scattered remnants of a once continuous stratum.

All of the islands are very low, seldom higher than about 10 or 15 feet above the high tide level, yet covered by a dense vegetation and reinforced by partial development of beachrock, they are able to withstand any type of storm. However the most important factor contributing to the stability of these islands are the breakwater effect of the surrounding reef and the rather protected position of some of these reefs themselves (relative to adjacent reefs). The prevailing wind is the southeast trade (April to October) and for days this wind can blow at from 15 to 20 knots. As most of the islands are situated on the lee of their reefs there is a relatively large expanse of reef in front of the island which has the effect of attenuating the force of the waves reaching it. The higher part of any high tide (i.e. part effective in island erosion) only lasts for about 2 hours before and 2 hours after the time of high tide (this being followed by the low tide 6 hours later), the actual time during which waves attack an island is not very great. However, during a cyclonic storm a wind from the northwest combined with a high tide could do extensive damage to an island as there would be much less reef to protect it. All of the cays of the Capricorn Group are located on a shallow submarine platform, therefore a strong oceanic swell is seldom experienced. Less obvious but probably important is the effect the tidal stream has on reducing the force of the sea adjacent to a reef. Here the tidal stream reverses its direction with the change of tide and can flow at rates exceeding 2 1/2 knots (Australian Pilot Vol. IV, 1962), however I believe that during mid-tide at the time of spring the velocity of the tidal stream can be even greater and could act as a buffer to reduce the impact of waves coming across the reef towards an island.

Various surveys of the islands of the Great Barrier have been carried out in the past (e.g. Spender, 1930, Steers, 1937) during which some or all of the islands of the Capricorn Group were visited briefly. From this work evolved several classifications of islands and their reefs, but the first realistic classification was presented in 1950 (Fairbridge, 1950). Using it the two categories relevant to the Capricorn Group are as follows:

Type 2. Vegetated Sand Cay. Moderately stabilized, generally with beach rock. In this group I would include all the sand islands of the Capricorn Group.

Type 3. Shingle Cay, with or without vegetation. Moderately stabilized and widely distributed, generally found on smaller more exposed reefs. In this category I would put One Tree Island.

All of the cays of the Capricorn Group are composed of material derived from the reef upon which they have formed. This material is either in the form of sand or else coarse fragments of reef rock (shingle or rubble), coral skeletons, mollusk shells, etc. All or most of the above has an organic origin; the sand is made up of small fragments of reef rock, tests of foraminifera, Halimeda fragments, and small particles of coral skeletons, etc. Reef rock is a conglomerate of the larger fragments derived from the reef cemented together with a calcareous cement produced by the fusing of small sand or silt-sized particles. Wind driven waves and to a lesser extent, tidal streams are responsible for the transportation and deposition of the material. Once the deposit is above the level of the highest tides the wind is important in forming and shaping it.

The genesis of the sand islands can be explained by the operation of two factors:

(1) The mass transportation of sand across the reef flat from the windward areas towards the lee by wind-driven waves moving across the reef flat during high tide and to a lesser extent by the tidal stream. During low tide sand is transported by drainage currents as well as by wind-driven wave action. Most reefs are slightly lower at their western ends (lee) and since the highest part of the whole reef is generally the outer rim or margin (reef crest) when the level of a dropping tide falls below this rim all of the water contained within the reef flat will drain towards the lee. The sand transported to the leeward part of a reef would be deposited here when the current looses some of its velocity as it meets an obstruction or enters the shallow water of the lee reef flat. Once a sand bank is formed the process of depositing sand continues until equilibrium is reached and erosion begins to have a negative effect. During low tide there is some drainage out along the sides of a reef and on the windward areas, association with the so-called "groove and buttress system" often found here (Fig. 10).

(2) The second factor in the genesis of the sand cays is the effect of cross-swell depositing sand on the lee of the reef. The southeast swell upon encountering a reef is refracted around the reef, the waves approaching more or less normal to the margin. The resulting turbulence will cause sand to be deposited in a very localized area on the lee of the reef. The above only takes place during high tide and periods of heavy swell (Fig. 10).

The cays consisting of coarse coralline shingle or rubble have a different mode of origin. One Tree is the only island of this type in the Capricorn Group, although Wilson has much coarse material in its composition and several reefs have rubble banks that are exposed during half tide on their windward sides, e.g. Heron and the nearby Wistari. Shingle cays are formed by the action of waves accumulating material and washing it up on the reef into ridges or banks. An examination of One Tree Island discloses a series of concentric ridges more or less

parallel to the margin and extending well into the island. It was formed as successive ridges of rubble accumulated, each tending to fuse with the next until a structure of some size evolved, able to support vegetation. These accumulations of rubble always tend to form towards the windward sides of a reef because here the wave action is the strongest, and this is necessary in order to move this type of material. Such highly irregular fragments interlock, giving the cay some resistance to erosion.

The question arises as to where the rubble, and to a lesser extent sand, comes from. On One Tree and the various rubble banks situated on the windward sides of their reefs the area producing rubble or shingle is very restricted as it must be to windward of the island. The normal life and death processes of the animals and plants living on the windward of such a reef as One Tree could not account for the enormous amount of coarse coralline rubble found there. This is especially true of reefs as far south as those of the Capricorn Group.

I believe that the material made available to form the cays, especially the coarse rubble or shingle, was produced by wave action in the past, when a drop in the level of the sea left the reef standing higher out of the water. Immediately the sea would begin to erode the reefs down to about their present height and in so doing would produce large quantities of debris. Most scientists concerned with the problem of sea level changes agree that there have been some marked changes in the past, at times the sea being higher than at present and at other times lower. However there is no agreement as to the exact height at any given time, but it is generally accepted that the last change was a drop of at least several feet, probably more. All of the reefs are now effectively planed down, and although some irregularities probably exist, most are stabilized at their present level and are covered by a veneer of living coral and other reef-dwelling organisms. The gradual destruction and depth of these organisms, to be replaced by others, would furnish sufficient material to maintain the existing islands in a state of equilibrium, just balancing the loss due to erosion.

HUMAN INTERFERENCE

At the present time human interference with most of the uninhabited cays of the Capricorn Group is not extensive. This is probably due to the number of visitors being relatively low, but alas the quality of many of these visitors is also very low. Whether persons going to these islands do so in their boats (these would be the lesser number) or via a charter boat, they for the greater part seem intent on enjoying themselves to the utmost, and regrettably, to give little thought to preserving the pristine character of the island on which they find themselves. As the islands become more accessible the increasing number of visitors, unless controlled, will eventually destroy these areas of great natural beauty. Some of the cays are state parks, but all are worthy of preservation.

The disappointment must be intense to one who, after much planning and dreaming of a vacation on a coral island, finally lands upon a beach and sees first an open rubbish tip, numerous empty beer bottles and some hideous tables and chairs made of beach flotsam. This same person is very likely to leave the island just as he found it! The effect is cumulative!

Northwest Island was many years ago the site of a cannery and evidence still remains of this activity in the form of an old shed and a few relics of boilers and machinery. There is a very small one-room cabin of more recent construction. The scattered heaps of rubbish and tins attest to the fact that Northwest Island is visited rather frequently. As it is the largest of the group, the actual area interfered with is very small, and old boilers, sheds, etc. are in an area about 200 feet square. There are cats and chickens but their effect on the natural flora and fauna is probably not significant on so large an island.

Masthead Island is also quite large and is visited frequently, but probably less so than Northwest and there is no fresh water and no sheds. The main camping area of Masthead is in a delightful grove of Casuarina on the western end of the lee side. Here the effect of man is much less than at Northwest and some crude furniture and perhaps a small rubbish heap are the only evidence of campers. There are no introduced animals but at least several clumps of a kind of cactus of prickly pear which may be spreading slowly.

Tryon Island, with Masthead Island, is probably the least affected of the larger islands of this group. Tryon is very similar to Masthead in that again the camping area is on the western end among Casuarina trees and the only sign of visitors is a crude table with some scattered tins and bottles.

Wreck Island has suffered the most from human interference. In 1950 an exploratory bore was put down, there were many men and some machinery on the island at this time. Later on, it was surveyed, possibly for a proposed airstrip, and much vegetation was cut down. During the summer of 1968 a party of campers lived on Wreck for about a week and when they left there was a large open garbage pit, many rusting tins, several ugly bits of furniture and a latrine had been constructed in the center of the most lovely grove of Pisonia. The pristine character of this island has been all but destroyed and may never return again. Rats introduced probably at the time of the bore are a nuisance and will certainly prey on young sea birds when available.

Wilson Island was once very lovely with its extensive grove of Pandanus. Now the Pandanus are drastically reduced due, so I understand, to a fire followed by a cyclonic storm. The fire would almost certainly have been set by visitors. Now this cay is visited regularly by an excursion from the hotel on Heron Island and this has its effect in a permanent rubbish tip and some crude tables.

One Tree Island shows the least human interference and yet has been visited by many persons, a high percentage of which would be scientists. There is almost a total absence of old tins, beer bottles, and the usual rubbish tips.

Erskine is very small but unfortunately the abundant evidence of visitors is here in the form of litter. Old tins, bottles and crates may be found scattered about.

In the absence of any form of control it is important that any person likely to visit these islands be informed that they are not to be misused: this should be presented in an unmistakable manner. It all depends on educating the individual to respect and treat with consideration areas of natural beauty which belong to all.

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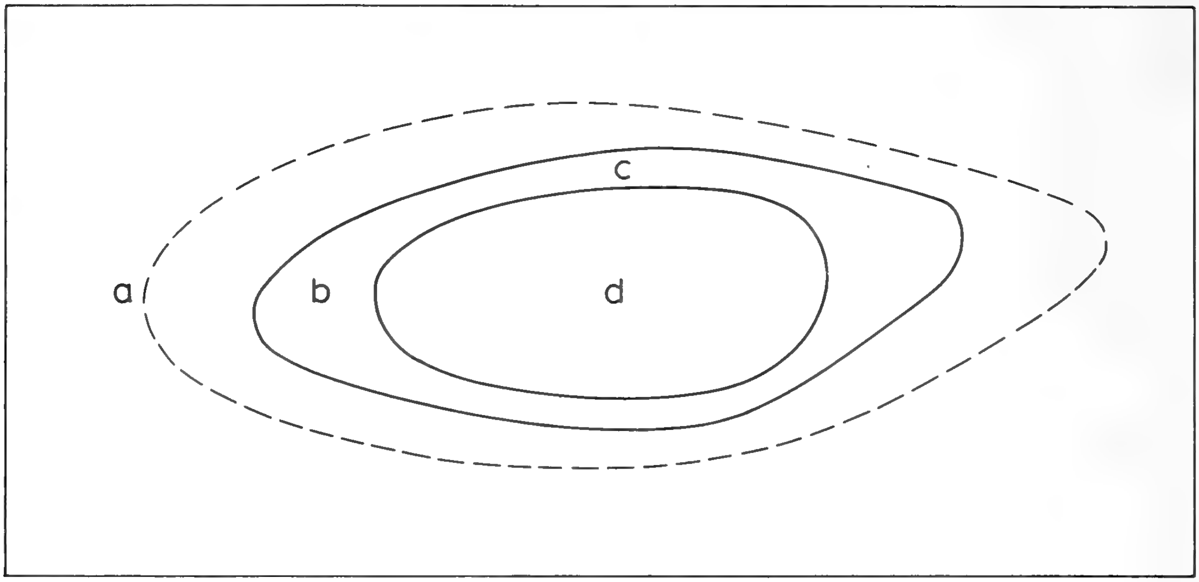
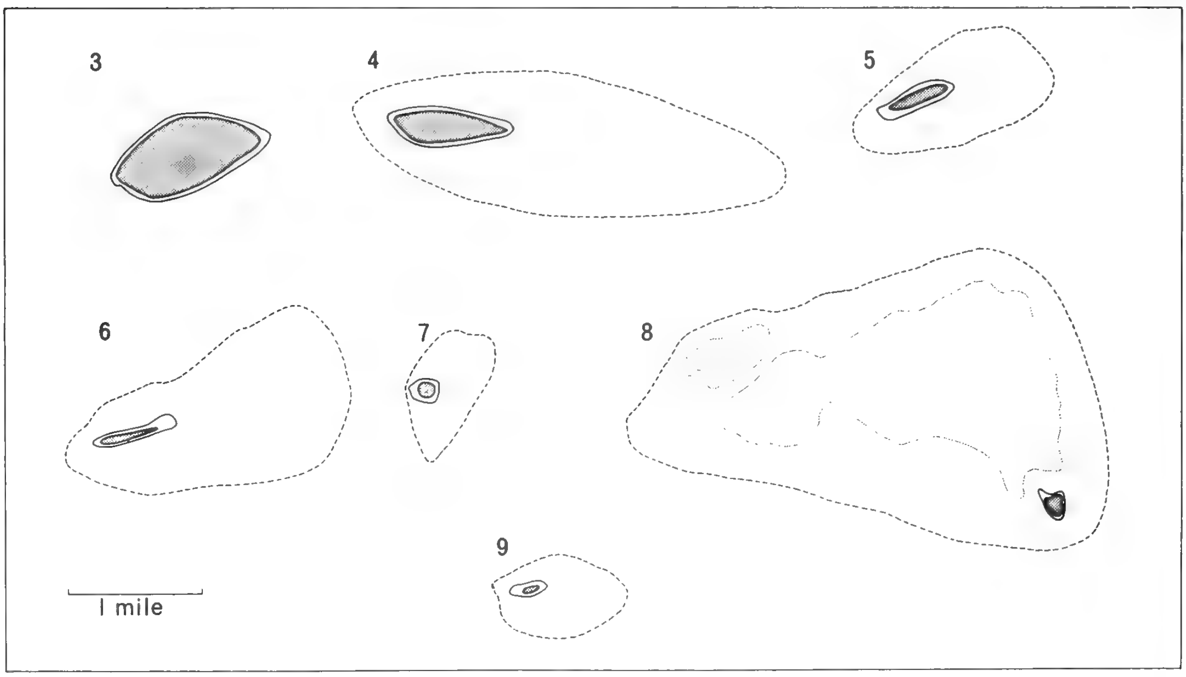


Fig. 2. Typical sand cay showing vegetation zonation

a. Beach margin; b. Casuarina grove often found on ends of island; c. outer zone of Tournefortia, Scaevola and Casuarina; d. inner zone of Pisonia.



Figs. 3-9: 3. Northwest Island. 4. Masthead Island. 5. Tryon Island. 6. Wreck Island. 7. Wilson Island. 8. One Tree Island. 9. Erskine Island.

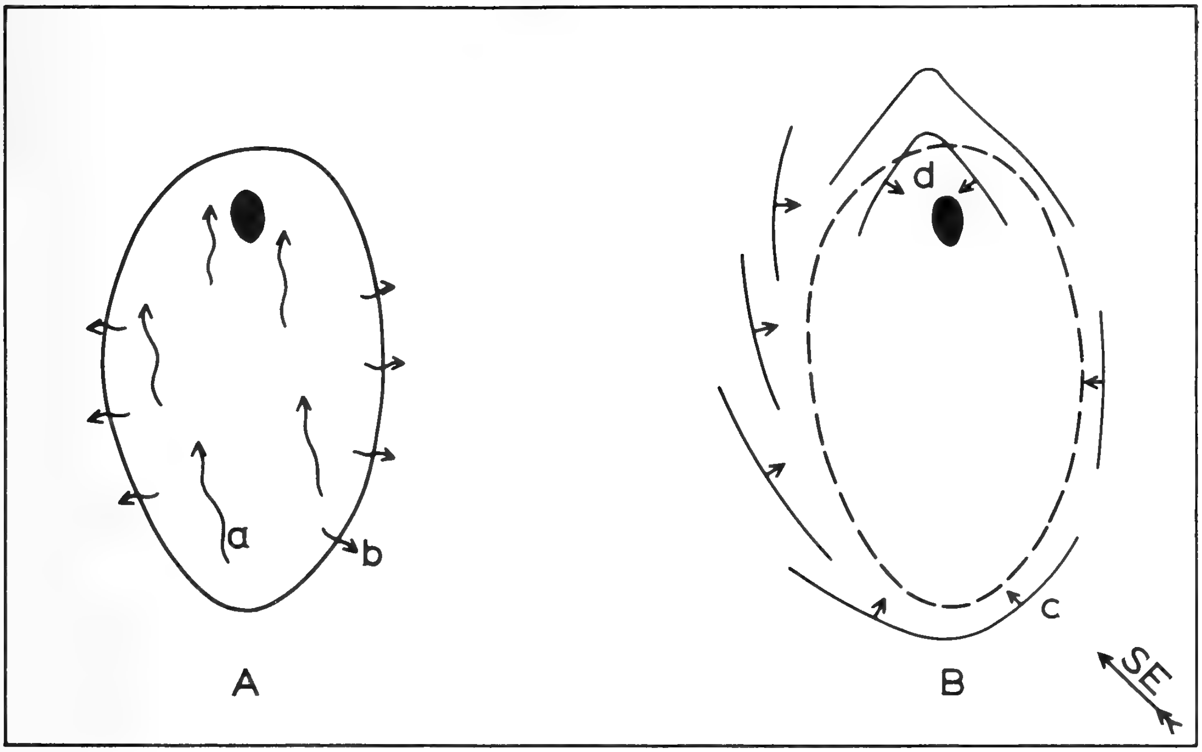


Fig. 10. Typical reef illustrating factors effective in genesis of a sand island.

A. Reef at low tide
a. general current from windward to leeward;
b. lateral drainage across reef crest

B. Reef at high tide
c. wave fronts advancing on reef and being refracted around margins; d. cross swell on lee of reef due to refraction of waves.

Plate 1. View along beach, lee side, Northwest Island.

Plate 2. Old cannery building on Northwest I.

Plate 3. Results of erosion, south side, Masthead I.

Plate 4. Straight line of <u>Casuarina</u> on dunes, north side, Masthead I.

Plate 5. Casuarina grove, west end, Masthead I.

Plate 6. Spreading prickly pear, south side, Masthead I.

Plate 7. Well developed Pisonia forest, interior of Masthead I.

Plate 8. Casuarina grove, east end, Masthead I.

Plate 9. East end of Tryon I.

Plate 10. Latrine in center of camping area, in Pisonia forest, Wreck

Plate 11. Debris left by visitors, Wreck I.

Plate 12. Traces of weekly visits of tourists from Heron I. on Wilson I.

Plate 13. Traces of weekly visits of tourists from Heron I. on Wilson I.

Plate 14. Beachrock on windward side of Wilson I.

Plate 15. Devastated Pandanus on Wilson I.

Plate 16. Low vegetation and Pandanus grove, One Tree I.

Plate 17. Coral rubble from which One Tree I. was formed.

Plate 18. North-facing embayment, One Tree I.

Plate 19. Brackish pond in center of One Tree I.

Plate 20. Sea eagle's nest, possibly that recorded by Jukes in 1840, One Tree I.

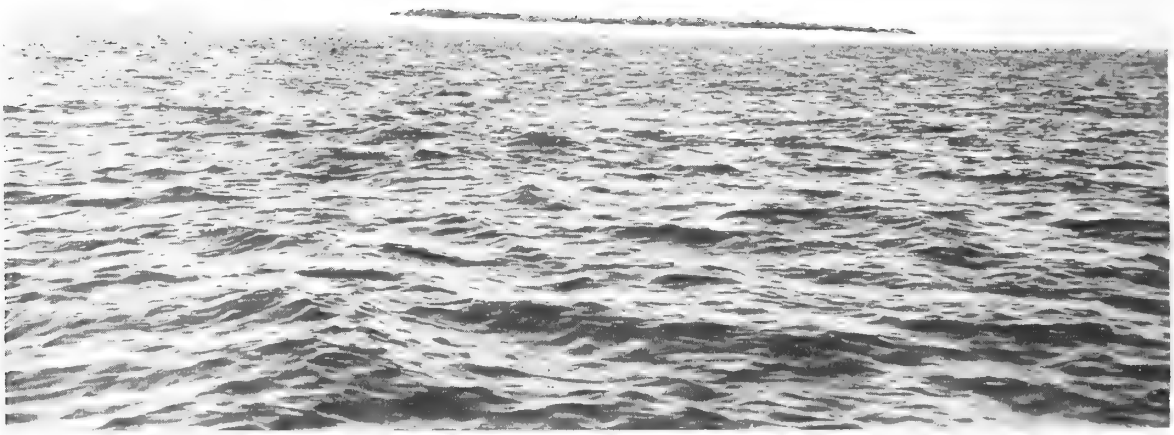


Plate 21. Erskine I., from 1 mile off.

Plate 22. Piled up slabs of beachrock, north side, Erskine I.

Plate 23. _Tournefortia_ and _Scaevola_ above slightly cliffed beach margin, Erskine I.

Plate 24. Erskine I. viewed across rubbly reef flat.

ATOLL RESEARCH BULLETIN

No. 143

THE SAFE USE OF OPEN BOATS IN THE CORAL REEF ENVIRONMENT

by S. B. Domm

Issued by

THE SMITHSONIAN INSTITUTION

Washington, D. C., U. S. A.

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THE SAFE USE OF OPEN BOATS IN THE CORAL REEF ENVIRONMENT

by S. B. Domm

INTRODUCTION

For the past two and a half years I have been employed at Heron Island Research Station, Great Barrier Reef of Australia. The work has entailed much time in small, open boats in many weathers. Often it was necessary to travel to reefs up to twenty miles away. Diving, collecting, and surveying often meant using boats in conditions that were potentially hazardous.

Small boats are available at the Research Station and, of the scientists that occasionally use them, few have any practical experience in such matters, yet more and more scientists are finding it necessary to rely on themselves. I have seen the most intelligent academics make incredible blunders when using boats, blunders that in slightly different circumstances could have had serious consequences.

It is my hope that these notes will provide useful information for those scientists working in the coral reef environment. Although written especially with the Great Barrier Reef of Australia in mind, this information should prove useful elsewhere.

BOATS SUITABLE FOR CORAL REEF WORK

For working around coral reefs a boat should be both maneuverable and of shallow draft. Light weight is also an advantage, except possibly in a boat used only for diving. When working on a small island that receives little protection from its surrounding reef it is often an advantage to be able to pull one's boat well up on the beach (usually with the help of a rubber roller), since such places offer few possibilities for a safe anchorage. A light boat is also very useful in that it can be "walked" over the reef crest, etc. when water is very shallow. However a lightly loaded aluminum boat is very subject to the wind, and can be blown along at a surprising speed. This can prove very troublesome at times, especially when one is trying to row.

I have had the most experience with aluminum boats and have found them to be quite satisfactory. They are quite light and yet strong and capable of carrying very heavy loads. A very good boat is the 17'6" DeHavilland "Hercules" which when powered by a 40 hp outboard motor is capable of carrying large loads in rough seas and yet when lightly loaded is fast and quite maneuverable. Another aluminum boat I have had much experience with is the 12 foot DeHavilland "Sea Otter". Powered by a 10 hp. outboard motor it will cruise nicely at about 12 knots with 2 persons plus gear. Even with a good load both these boats will retain enough freeboard to be relatively safe in rough seas. There are many other different makes of aluminum boats, all having advantages and disadvantages.

Although I do not recommend outboard motors for every use they appear to be ideal for work around coral reefs. A boat powered by an outboard engine is very maneuverable, especially if lightly loaded. This enables one to approach very close to a reef or to thread one's way through the patch reefs of a lagoon. It also makes loading or unloading passengers or equipment onto a reef easier. Experience with sizes of up to 40 hp. has proven to me that an Evinrude outboard motor can be a reliable and very versatile engine. An outboard motor can be removed easily from the boat, making it lighter for hauling up on the beach or on board a ship. It can be exchanged between one boat and another, is readily tilted up when in shallow water or at anchorage, and can even be run for short distances in a semi-tilted position if power is necessary in very shallow water. A shear or drive pin, or even a propeller can be replaced quickly and easily. One major disadvantage of any outboard motor is the high rate of fuel consumption. On occasion I have used two outboard motors, a large one for traveling from one reef to another, and then a smaller (e.g. 5 hp) one for going over a reef or when prolonged slow running is necessary (e.g. echo sounder surveys). The light weight and reliability of the modern outboard makes it very useful indeed.

A note on steering systems is appropriate since front steering by means of a steering wheel is becoming more popular. There appear to be advantages and disadvantages to both methods. Generally I prefer the simpler method of steering directly and there is much less of the unpleasant "pounding" in the stern than up forward, however it is usually much wetter. With wheel steering the motor cannot be tilted so readily nor motors exchanged so easily. A lightly loaded boat can pound in a most unpleasant manner up forward in a short, steep sea. Electric shifts, steering cables, etc. reduce the overall reliability of any boat. The steering wheel up forward on the other hand is much like driving a car, gives better vision in front and is usually much drier when traveling at high speed.

Various designs of jet propelled boats plus the already popular inboard-outboard may prove very useful for work on coral reefs. Generally

an inboard engine (especially diesel) is more reliable and more economical to run than an outboard; however most are heavier and more expensive than an outboard.

TIDES

The tides of the Great Barrier Reef of Australia are semi-diurnal, and unlike many coral reef areas of the world there is here a marked tidal range. In the southern part of the Reef the range is over 8 feet, elsewhere it can be much greater.

It is of the utmost importance for scientists working around coral reefs to have tide tables (which may need to be adjusted for outer reef areas), and to know the state of the tide. If tide tables are not available, it is an easy matter to determine the time of either low or high tide by marking the beach as the water advances or recedes. Knowing that the tide changes every 6 hours and that the time of the tide advances each day by approximately 50 minutes, one can approximate the time of any tide for days in advance.

It will save much trouble and possible damage to one's boat to mark out across the reef a channel clear of niggerheads, by driving poles into the reef or erecting markers of some kind. This will indicate when the water is sufficiently deep to enable a boat to come and go safely. On many reefs the lee, especially the western end, gives the best approach to an island or reef.

During the time I have worked at Heron Island I have seen many foolish mistakes made regarding the tides. It should be obvious that if one desires to do any work on the reef flat without diving, one must plan his visit to coincide with a low spring tide, when most of the reef flat will be exposed for about 3 hours (water only a few inches deep). It is also important to note that the height of the tides is not even; of the two highs in 24 hours one is higher than the other. For example, during the summer the lower of the two low tides occurs during the night.

Spring tides (having the greatest range) occur twice each month, coinciding very closely with the new and full moons. The height of any tide can be affected by the wind; the wind can pile water up on a reef or it can speed up the drainage of water from a reef flat. On a low spring tide there will usually be very little water on the reef flat from approximately one hour before until two hours after the time of low water, giving a maximum of 3 hours working time. When working in an enclosed lagoon one must be very careful not to get "trapped" in the lagoon by a falling tide.

For underwater photography the neap tides are often the best as visibility in the water is better then.

Tidal Stream

This aspect of the tides is often not so apparent as the vertical movement and varies both in intensity and direction. The tidal stream is usually called a current, and on the Great Barrier Reef it changes its direction with the change of tide. The highest velocity occurs with the spring tides and varies from 2 to 7 knots.

Information regarding the tidal stream can be found in the Australian Pilot, Sailing Directions, or other nautical publications, and is usually printed on charts using arrows to indicate directions. If one works on uncharted reefs it may be a good idea to find out the directions of the currents by the use of dyes. This information may influence one's choice of a work area. The wind can modify the strength or even the direction of a tidal stream, and it is possible that during neap tides a strong wind blowing against the stream may even reverse its flow. It is often necessary to time one's activities to coincide with the weakest tidal stream. Any collecting will be affected by the strength and direction of the current, especially when working in a channel between reefs, or on the windward or front of a reef. When working just off a reef it is easy to pick out swirls, or eddies of the tidal stream (tidal rip) as it flows past the reef and often the interface between the two bodies of water is very sharply defined. Generally the lee of a long reef is less affected by the tidal stream than the more windward areas. The stream is often felt on the reef flat during high tides.

A very important aspect of the tidal stream is that when it is flowing against the wind, a very steep and unpleasant sea can develop. This is especially characteristic of channels between adjacent reefs, or over very shallow areas. When traveling between reefs in an open boat with a wind blowing one should endeavor to choose the time when the tidal stream is favorable.

APPROACHING AND GOING OVER A REEF

To safely approach and go over a reef depends on being able to see the margin of the reef, and on knowing how much water covers it. With a high spring tide it should be possible to go over a reef just about anywhere, except on the windward sides of many exposed reefs where there are often large niggerheads, some of which may be over 5 feet high. The niggerheads usually occupy a rather narrow zone within approximately 100 yards of the outer reef margin. This zone should be navigated with caution! Often the niggerheads occupy the highest part of the reef (reef crest), which adds to their danger.

Proper use of tide tables and direct observation of water depth will enable one to ascertain whether or not there is sufficient water to go over a reef. It is also important to note that all reefs are not

of the same height, and that even on one reef the windward area is usually higher than the lee.

And now for the most important aspect of reef navigation near a reef--being able to see it! During good conditions a reef is very easy to see, the higher the observer the farther away a reef can be seen. From about one mile one can usually see the breaking surf, especially on the windward side as viewed from the lee. With any swell running this can be depended upon to indicate the presence of a reef. As one closely approaches a reef, marked color differences will become apparent; the deep blue of deep water changing to the green of shallow water and then the brown of the reef below the surface. Unfortunately these colors are only apparent under the following conditions: sun relatively high in the sky and at least a gentle breeze disturbing the surface of the water. Therefore, during early morning and late evening, with an overcast sky or during a dead calm, a reef becomes almost impossible to see except by the presence of surf breaking or thhe presence of a tide rip. From the above it is obvious that any scientist traveling around an unfamiliar reef should do so only during optimum conditions. Traveling at night except in a very familiar area can be extremely dangerous.

When going over a reef one should proceed slowly, watching for the brown patches that might represent niggerheads. If there is some uncertainty regarding the depth of water one should go very slowly, swim in and test the water, tilt the motor and row the boat across, run the boat across with the motor semi-tilted, or if the wind is favorable, just let it blow one across. When leaving a lagoon on a falling tide one can often use the current of escaping water to drift across the reef crest if the depth is insufficient to use the motor. If one is working extensively in a lagoon or over a reef flat it is very useful to use a small, shallow draft outboard motor.

Avoid a breaking surf at all costs, even the swell surging up on a reef during low tide on a calm day is potentially dangerous.

<u>Windward and leeward approaches to a reef</u>

The lee of a reef is the safest place to either work or land from a boat. During low tide, a reef is in effect a very good breakwater, with calm water behind it. Ideal conditions for landing are a wind blowing off the reef and a sea with practically no swell (this may never occur!). At such a time one can bring the bow of the boat up to a solid looking outcrop of the reef very slowly, and with one person holding the boat, the others can get out. The anchor can be put on top of the reef and the wind will hold the boat out. The boat must not be allowed to ride close to the reef. This sounds easy, but can in fact be very difficult to do without damaging the boat or injuring someone.

It is important to realize that any approach to a reef must be made with the boat normal (perpendicular) to the reef margin, as the boat can only be controlled by movement ahead or astern. A good practice in any tricky situation is to drop an anchor some way out from the reef, then as the approach is made, the anchor line is payed out until the boat is next to the reef. The first person out will hold the boat, the anchor line will keep the boat in position. The line can be made fast and another line or anchor put on the reef, thereby holding the boat between the two lines. This method of coming in on a line has many applications; a good example is beaching a boat through a surf. Here, the last stages of the approach might better be made stern first, as a wave breaking over the bow is less likely to fill the boat than one breaking over the stern. The above presupposes a light to moderate surf. In a heavy surf no attempt should be made to approach either a reef or an island.

A windward approach can only be attempted during very calm weather. Again this is often best done by running back from an anchor line, with the utmost care taken to insure that the waves do not throw the boat onto the reef. The anchors are used to hold the boat at just the right distance out.

The utilization of some natural features of a reef can often make landing much easier. For example if the reef margin is irregular, one often finds relatively calm areas just behind a small "headland" or projection of the reef. A well developed "groove and buttress system" can provide convenient little "harbors" from which one can safely land, even in fairly rough seas.

WIND AND CURRENT EFFECTS

The effect of the wind on the water is the most important factor influencing the use of small boats in working around reefs. In relatively shallow water areas like the Great Barrier Reef a very small increase in the velocity of the wind can, in a very short time, generate a very rough sea with short, steep waves. In such a sea traveling between reefs or working the more exposed parts of reefs is often unpleasant and can be dangerous. The effect of the tidal stream has already been mentioned. Experience with an area will enable a person to judge what conditions of wind and sea are most conducive to safe and reasonably comfortable working, although the pattern is often complex and not readily understood.

Usually I seldom travel between reefs if the wind is blowing harder than 15 knots, especially if I must drive into the seas. Running with the wind can be done at wind speeds of 20 knots or higher. Only very calm days are used to visit and work the very windward areas of most reefs. Any scientific project that will entail traveling over a mile or working the margins of a reef should have a program that is

flexible enough to accommodate changes in the weather. Given moderate weather conditions, for any wind or tide, there is usually some part of a large reef that can be visited. The lee of any reef is by far the safest place to work, the flanks are often characterized by rough water and the windward areas, except in a very calm sea, are dangerous.

When handling the lighter, outboard-powered boats in a wind, it must be remembered that they will tend to drift sideways very quickly. Any tricky maneuvering should be done directly facing the wind. The wind will also tend to blow the bow of the boat off-course since the bow is usually higher, and is less weighty. One has better control of a boat if it is run slowly up into the wind or current, rather than slowly along with it. This is important when picking up a person or a mooring float. When traveling any distance with an outboard boat it is best to go with the wind or waves. Excessive speed in rough seas is not recommended, as with a light planing boat it is possible to plane down a wave and bury the bows in a trough, or to be thrown sideways and lose control of the boat with possible disastrous results. It is safer to maintain at least a reasonable speed, as the boat is less likely to be filled by a cresting sea when the speed of the waves and the boat closely approximate each other. Heading into the seas or "punching into it" can be a wet and thoroughly unpleasant business unless at very slow speeds, yet it is perhaps safer in really rough weather. It is important when calculating fuel needed for a trip to remember that different sea conditions will require varying amounts.

Be cautious when working in an area where a change of wind direction can have serious consequences--in the tropics squalls can bring on very sudden changes in wind direction and velocity.

JUDGING THE DEPTH OF WATER

The color of open water on a clear day with a high sun and a breeze will indicate the approximate depth very well at close distances. Deep blue water is about 50 feet or more, light green or blue-green water from several feet to about 30 feet over a sandy bottom. Most important of all is brown, which indicates reef below the surface of the water (several inches to 20 feet).

Judging the depth of water over the reef flat is difficult because of varying clarity, wind effects, etc. Often only a few inches will determine whether or not one can use an outboard, therefore they are critical. The presence of niggerheads and other scattered debris complicates the picture. The best method by far is to have a marker on the reef. A little foresight here will save many broken drive pins and damaged propeller blades. When water depth is at all questionable, never rely on your eyesight to determine it. Sometimes, especially with high cloud, polaroid sunglasses enable one to pick out the margins of a reef more easily than with the naked eye.

NAVIGATION AND BEARINGS

This is not the place to explain the principles of navigation; one must assume that any scientist traveling by open boat out of sight of land is able to read a chart and plot a course. However a few notes might prove helpful. When determining one's position on a reef, it has been my experience that it is best not to rely too much on bearings taken with a hand compass. The motion of a small boat is usually so great that bearings can only be considered approximate. Horizontal angles taken with a sextant are best when plotting one's position from a small boat. It is now possible to buy small inexpensive, plastic sextants which will stand up to such rugged conditions and yet are sufficiently accurate for most work.

Navigating between reefs with cays on them need not be so precise if the distances are not great, as islands can usually be seen from 2 to 8 miles away. However it is not wise to rely on eyeball navigation as the visibility at sea is a very uncertain thing indeed. Always carry a compass. The choice of compass depends on many factors: whether it will be permanently attached to the boat, its position in the boat, the location of the motor, etc. When steering from the stern and using a small portable compass, I have found a small box compass made by the Swedish "Silva" company to be very satisfactory. This compass uses two parallel lines to enable one to steer a preset course and has the advantage of allowing one to sit at some distance from the compass and still steer a course. Other types require one to be able to read the actual degree markings which necessitates a fairly large compass close to one's face (awkward requirements for some small boats). I might add here that steering a compass course from a small boat traveling at any speed is at best a rather uncertain business. I shall not treat the problem of compass deviation here, except to say that I have experienced little with aluminum boats and the compass at least 6 feet from the motor.

It is useful when working a given area to cut or trace out the appropriate section of a chart including a compass rose, and to lacquer or varnish it to a board. With a set of parallel rules, this will be most convenient for plotting one's position.

ANCHORS AND MOORINGS

All boats should have at least one anchor aboard at all times, plus sufficient line or chain to be able to anchor in most depths of water likely to be encountered. On reefs located in shallow shelf areas it is possible to carry enough line to anchor practically anywhere, and in the advent of motor failure, anchoring and waiting for help can save time and trouble, perhaps even lives. With the development of various synthetic ropes, especially nylon, very strong line comes in small diameters, and it is now possible to carry enough line to anchor in at

least 30 fathoms of water. A tangled and snarled heap of line in the bottom of the boat is worse than useless, and the only method to carry a long line in a small boat is on some kind of spool, which should have a hole through the center so the line can run free, with the spool spinning on a bar. The anchor should be attached directly to a length of chain, then to the line. The longer the chain the better, but because of its weight, 30 or 40 feet are often all that one can take. The weight of the chain helps to keep the pull on the anchor horizontal, avoids sudden jerks and it cannot be cut by rubbing over sharp obstructions on the bottom.

The two most common types of anchors, and in my opinion the best, are the standard "pick" anchor for coral or rock, and the "Danforth" for sand or mud. The choice depends on the conditions anticipated; often one is justified in carrying both. Note: the Danforth anchor will hold in coral, but the pick anchor is almost useless in sand. However the Danforth anchor is liable to get so well "hooked" in coral that it is very difficult to extricate without diving. For small boats (12 to 16 feet) it is often a good idea to have an anchor slightly larger than is recommended for the size of boat, as the Danforth anchor should be fairly heavy in order to work efficiently.

When anchoring, the best procedure is to come slowly up wind or current until the desired spot is reached and then to reverse and let the anchor go as the boat backs away. The amount of line let out should be approximately 3 times the depth of water, more may be necessary in sand to insure a good hold. To bring up the anchor the best method often is to have one person run the boat ahead while the other brings in the slack line until it is vertical, then a good tug from above or even slightly ahead will usually free the anchor. If the anchor has become fouled, one should try pulling from different directions, using a series of sharp tugs. Anchor with care, especially at the end of the day. Many boats are lost every year due to faulty, inadequate or even nonexistent ground tackle.

When anchoring next to a reef during low tide make sure the boat is far enough out so it doesn't swing in against the reef with a change of wind. Two anchors are often required to hold a boat properly. Near the reef crest during high tide, note that waves may begin to break as the tide ebbs and water level falls.

A mooring is nothing more than a length of chain or line, secured to a heavy object that cannot be moved by a boat pulling against it. It is very useful when one works in one area for an extended period of time, and can be made by wrapping a line around a boulder. A float will help see and pick up the end of the line. Some advantages of a mooring are: the line is much shorter than an anchor line and therefore the swing of the boat will be much less, reducing the possibility that change of wind will cause it to be stranded or damaged with the falling tide. A mooring can be made more secure than anchoring as the shorter chain can be much heavier and can be attached to a heavy cement block.

It is worthwile, especially in remote areas, to give some thought to the securing of one's boat for the night or with the approach of bad weather. The loss of the boat during a sudden storm or change of wind at night could be embarrassing, especially as it is simple and inexpensive to secure it properly.

SAFETY MEASURES

Before going anywhere in a boat someone on shore should be informed of the destination and estimated time of return; this is very important. All boats should have aboard at all times the following items: anchor plus sufficient line, if boat is small enough a pair of oars, day and night distress flares, a large bailing bucket, sufficient life preservers for all persons aboard, a small compass, a container of drinking water. If a motor is used, some tools and spare parts should be in the boat; if the motor is an outboard carrying extra shear or drive pins, a set of spark plugs and even another propeller is a good idea. The above may seem like a lot of "stuff" but in terms of human life or even inconvenience it is not excessive.

If possible boats should have built-in buoyancy, which can be in the form of foam plastic blocks fastened underneath the seats.

It is a good idea to time one's return well before sunset, so that if necessary a search can be made before it gets dark. Perhaps the best safety device is one of the small transistorized "walky-talky" radios. They are rugged and the more powerful ones have a range of up to 20 miles in a direct line over the water. This will enable one to remain in contact with the base, and have much more freedom in changing plans, without being forced to rigidly conform to a prearranged schedule.

Now, a final word concerning safety while in the water. When diving from a boat in an area subject to a tidal stream it is most important to dive up-stream from the prevailing current, then in the case of exhaustion or a cramp a person can drift back to the boat. A line trailing in the water behind the boat is also a good idea. Because of friction the tidal stream is not as strong on the bottom, and therefore can increase almost unnoticed by a busy diver, who upon surfacing can find himself being swept away with an empty air tank.

ATOLL RESEARCH BULLETIN

No. 144

THE VASCULAR FLORA AND TERRESTRIAL VERTEBRATES OF VOSTOK ISLAND, SOUTH-CENTRAL PACIFIC

by Roger B. Clapp and Fred C. Sibley

Issued by

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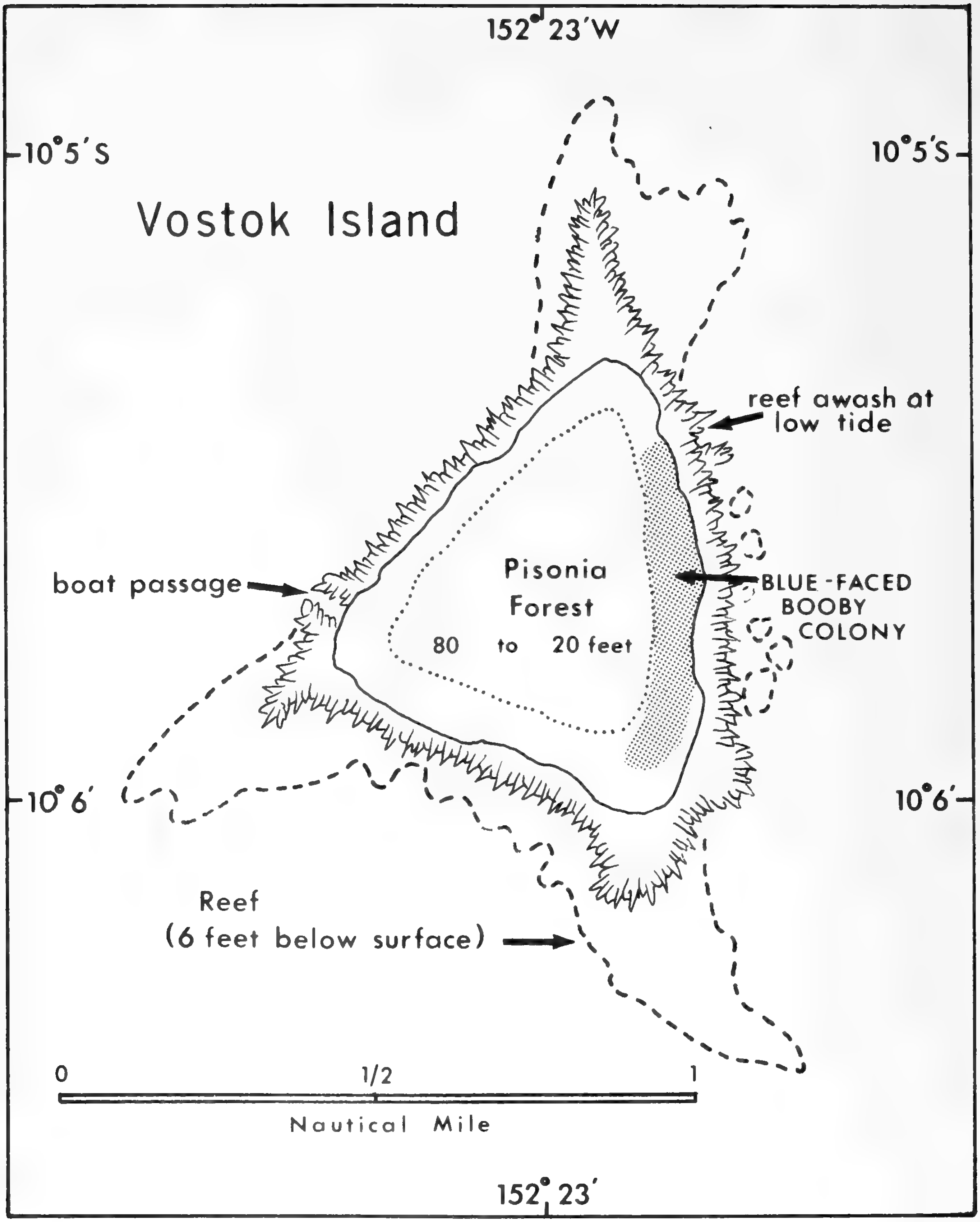

Figure 1. Map of Vostok Island (modified from Bryan, 1942).

THE VASCULAR FLORA AND TERRESTRIAL VERTEBRATES OF VOSTOK ISLAND, SOUTH-CENTRAL PACIFIC [1/]

by Roger B. Clapp[2/] and Fred C. Sibley[3/]

In 1965 Vostok Island was visited briefly by Sibley and five members of the Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institution. Observations were made from 0900 15 June through 1300 16 June and collections were made of vascular plants, fish, reptiles, birds, mammals, and avian ectoparasites. A small number of seabirds was banded.

Previous information on the biota of Vostok is remarkably scant, limited largely to a few semi-popular accounts (e.g., Bryan, 1942) and a short note on vegetation (Fosberg, 1937). No professional biologists had landed on the island and almost nothing was known of the avifauna, nor were the specific identities of the mammal and reptiles occurring there known.

This paper fills some of the gaps in our knowledge of the biota of Vostok, reports recent observations of the vascular flora, and provides a summary of earlier information.

DESCRIPTION

Vostok is a small, triangular coral island in the southern Line Islands, located at 10°06'S and 152°23'W (Figure 1). It lies 86 miles north-northwest of Flint Island and 125 miles west of Caroline Island. It is about 60 acres (Maude, 1953), or 0.24 square kilometers, in area, and the land surface is no more than 3 to 4.6 meters above sea level.

1/ Paper No.60; Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D. C.

2/ Pacific Ocean Biological Survey Program, Smithsonian Institution.

3/ Point Reyes Bird Observatory, Bolinas, California.

The south and west beaches extend to a maximum width of about 45 meters and rise abruptly to a crest that coincides with the edge of the forest that occupies most of the interior of the island. At high tide waves reach the top of the west beach. Recently deposited sand at the top of this beach, and eroded soil at the forest edge, indicate that storm waves occasionally deposit salt water in the interior. The east beach ranges in width from 23 to 30 meters. Above it is a flat area of coral sand and beach rubble that is as much as 90 meters wide at the southeast point.

VEGETATION

Fosberg (1937) reported that the flora of Vostok consisted of but two plants, *Boerhavia repens* L. (as *B. diffusa*) and *Pisonia grandis* R. Br. on the basis of observations and collections made by Captain W. J. Anderson in 1935. These were also the only two vascular plants seen and collected by the POBSP in 1965. Specimens:

Boerhavia repens L.
Anderson s.n. (BISH, US); *C. R. Long 3191*, *3202*, *3203*, *3204*, *3208* (all Univ. Hawaii).

Pisonia grandis R. Br.
Anderson s.n. (BISH, US); *Long 3192* (Univ. Hawaii).

The central portion of the island is occupied by a triangular stand of *Pisonia* forest that has been wind-sheared by easterly winds (Figure 2). Moving westward from the eastern edge of the forest, the *Pisonia* becomes successively denser and taller, reaching a height of about 30 meters at the edge of the west beach. No seedlings were found, but sprouts from fallen trees and exposed roots were numerous. No fruits were found.

A few *Boerhavia* plants were found on the sandy edges of the clearings but the most vigorous growth was found in a stand running from the north to the southeast point. This stand varied from about 3 to 20 meters in width.

On the floor of the forest is a thick humus (to 35 cm) composed of decayed leaves and wood. Crusts of a blue-green alga were found on the humus, rotting tree trunks, and rocks. Occasional clearings within the forest are also covered with a thick humus that overlies a phosphatic hardpan.

NON-AVIAN VERTEBRATE FAUNA

The only reptile found on the island by the POBSP was the Azure-tailed Skink (Emoia cyanura) of which three specimens (USNM 158350-158352) were collected. These skinks were common and appeared to be most abundant on the forest floor. This species had not been previously recorded from Vostok, although Bryan (1942) reported that "lizards" occurred there. No geckos were seen, but no search was made for them after dark when they would have been most readily found. Several turtles, presumably the Green Turtle (Chelonia mydas), were seen swimming offshore but no nests or signs of their activity were found on the island.

Rats have been known to occur on Vostok since 1935 when they were seen (but not identified to species) by Anderson (undated). Twelve specimens (USNM 361438, 441-449) (two specimens were apparently lost in transit) collected by the POBSP proved to be Polynesian Rats (Rattus exulans). On a geographic and mensural basis (Table 1) these rats appear to belong to the race R.e. exulans, widespread in the Polynesian area. They were abundant throughout the forest but were apparently most numerous in areas where the large Pisonia were interspersed with shorter trees, and under Black Noddy colonies.

Rats were seen feeding on stems and leaves of Pisonia and Boerhavia and one was seen feeding on the carcass of a Black Noddy. A coconut crab (Birgus latro) was seen feeding on a dead rat.

AVIFAUNA

Prior to the POBSP survey only two species of birds were found from Vostok. On 22 October 1884 J.R.H. MacFarlane visited Vostok from the H.M.S. Constance and "obtained two specimens of the small Black-cheeked Noddy, Anous melanogenys [= Black Noddy, Anous tenuirostris], and some of their eggs" (MacFarlane, 1887). W. J. Anderson (ms.) noted that "white love birds" [= White Tern, Gygis alba] were present when he visited the island from the motor sampan Islander in 1935.

In the following annotated list of POBSP observations and collections of Vostok birds, the figures in parentheses are an estimate of the total flying population, i.e., breeding and nonbreeding adults, subadults and immatures. All specimens were collected on 15 June 1965 except the Golden Plover which was collected the following day.

Annotated list of birds

BLUE-FACED BOOBY (475 ± 50) Sula dactylatra

Blue-faced Boobies nested solely on the coral rubble on the east side of the island. Nests were scattered uniformly over the area. A

Table 1. Measurements (mm) and weights (g) of specimens of *Rattus exulans*

Museum No.	Sex	Head and Body	Tail	Hind Foot	Ear	Weight
USNM 361442	♂	105	155	29	18	47
361445	♂	125	148	28	18	51
361446	♂	150	165	30	19	88
361447	♂	130	160	27	18	62
371448	♂	147	165	29	19	82
______ *	♂	138	162	29	19	82
361438	♀	128	155	26	17	47
361441	♀	132	163	29	17	70
361443	♀	118	______	27	18	65
361444	♀	140	160	29	18	65
361449	♀	110	143	26	17	30
______ *	♀	113	140	27	18	38

* Data from measurements of specimen evidently lost in transit.

complete count of nests revealed: 78 with 2 eggs, 19 with 1 egg, 5 with small young, and 9 with large young. The number nesting in mid-June 1965 was 111 pairs. The total number of breeding pairs for 1965 was undoubtedly larger, since many prenesting pairs were seen standing about. This observation and the data obtained by the nest count suggest that the primary period of egg laying is May through June or possibly July. In addition to the above birds, a small number of immatures were seen that were apparently no longer dependent on their parents for food. Presumably these were young that fledged late in the preceding breeding season. A roosting club of about 75 boobies was found at the south end of the nesting area. Five of these birds had been banded on islands of the Phoenix and Line groups 11 to 19 months previously. POBSP personnel banded 317 adults, 7 immatures and 6 nestlings. Two recaptures of Vostok banded birds have been recorded subsequently from the Phoenix Islands (Table 2).
Specimens: 3♀♀, all three were collected from nests with two eggs. USNM 495693, ovary 20x8 mm, largest ovum 13x5 mm, weight 1660 g; USNM 495694, ovary 35x10 mm, largest ovum 5 mm, weight 1373 g; USNM 495695, ovary 10x6 mm, largest ovum 2.5 mm, wt. 2020 g.

BROWN BOOBY (25 ± 5) *Sula leucogaster*

Seven nests were found, 4 with eggs, 1 with a small chick, and 2 with large chicks. This count was probably complete.

All nests were on the ground on the east side of the island near or under the forest canopy, and all but one were within one or two meters of its edge. The exception was 3.5 to 5 meters within the forest, but this nest adjoined a man-made lane.

Table 2. Movements of Blue-faced Boobies involving Vostok Island

Birds banded on other islands recaptured on Vostok 15-16 June 1965

Band Number	Where banded	When banded	Age when banded	Nautical miles traveled	Direction traveled	Recaptured as
737-21939	Jarvis I., Line Is.	14 Mar. 1964	Subadult	839	SE	Adult male* in roosting club
737-22604	Enderbury I., Phoenix Is.	17 Nov. 1963	"	1,172	ESE	Adult female in roosting club; had been banded in roosting club on Enderbury
737-48497	Jarvis I., Line Is.	14 Mar. 1964	Adult	1,172	"	Adult male in roosting club
757-66538	Birnie I., Phoenix Is.	8 Nov. 1964	Immature	1,186	"	Adult male* in roosting club
757-67888	Phoenix I., Phoenix Is.	12 July 1964	Adult	1,139	"	Adult female in roosting club
757-67904	" "	" "	"	"	"	Adult male; status undetermined

Birds banded on Vostok 15-16 June 1965 recaptured on other islands

Band Number	Age when banded	Where recaptured	When recaptured	Age when recaptured	Naut. miles traveled	Direction traveled	Remarks
587-82671	Immature	Phoenix I. in Phoenix Is.	10 Oct. 1966	Adult female	1,139	WNW	Captured in roosting club
757-89930	Adult	Enderbury I. in Phoenix Is.	14 Feb. 1966	Adult	1,172	"	Evidently not breeding

* These birds were sexed by voice at a period in the development of the Blue-faced Booby when differences in voice are not a reliable method of differentiating the sexes (POBSP unpub. data).

One immature and several nonbreeding adults were also seen. An adult, the immature, and the two large chicks were banded.
Specimen: ♂, USNM 495690, testes 14x5 mm, wt. 1065 g.

RED-FOOTED BOOBY (3,000 ± 1,000) *Sula sula*

An estimated 1,000 nests were found in *Pisonia* trees throughout the forest. Nests ranged from *ca* 4.5 meters above the floor in the small trees on the east side of the forest to *ca* 27 meters in the taller trees further to the west. Members of the field party climbed to some of the lower nests and found eggs and young. From the ground young were seen in some of the higher, inaccessible nests.
Specimens: ♂, 2 ♀♀ . USNM 495103, ♂, testes 15x6 mm, wt. 803 g; USNM 495104, ♀, ovary 16x8 mm, largest ovum 3 mm, wt. 873 g; USNM 495701, ♀, ovary 18x10 mm, largest ovum 4 mm, wt. 766 g.

GREAT FRIGATEBIRD (4,500 ± 1,500) *Fregata minor*

An estimated 1,500 nests, most of them at heights of 9 to 27 meters, were widely distributed in the trees. POBSP observations, though limited because of the inaccessibility of most nests, indicate that these Frigatebirds were in the early stages of their breeding cycle. Many males with expanded throat pouches and several birds gathering *Boerhavia* stems and *Pisonia* twigs for nesting material were seen. The few nests that were examined contained eggs. It is possible that very small young may have been present, but none could be seen from the ground.
Specimens: 2 ♂♂, 1 ♀. USNM 495089, ♂, testes 24x13 mm, wt. 990 g; USNM 495091, ♂, testes 13 mm, wt. 757 g; USNM 495090, ♀, largest ovum 30 mm, wt. 1358 g.

LESSER FRIGATEBIRD (500 ± 125) *Fregata ariel*

Lesser Frigatebirds were seen sitting on nests in one compact colony in the tops of a few trees in the east-central part of the forest. An estimated 100 nests were present but their contents were not checked. Since no young could be seen from the ground and since displaying males were not recorded, the nests presumably contained eggs, small young, or both.
Specimens: 2 ♂♂. USNM 495082, testes 25 mm, wt. 800 g; USNM 495706, rt. testis 11x4 mm, wt. 614 g.

GOLDEN PLOVER *Pluvialis dominica*

A flock of nine plovers was seen on 16 June on the sand at the southwest corner of the island. One was collected.
Specimen: USNM 495721, ♂, testes 2x4 mm, wt. 126 g.

BRISTLE-THIGHED CURLEW *Numenius tahitiensis*

Four Bristle-thighed Curlews, one of which was collected, were seen foraging along the beach on 15 June. A single bird, probably one of the above, was seen the following day.
Specimen: USNM 495733, ♂, testes 7x1 mm, wt. 360 g.

WANDERING TATTLER *Heteroscelus incanum*

A single bird was noted along the beach on 16 June. The flock of 19 unidentified shorebirds seen the previous day may have been of this species.

SOOTY TERN (40-50) *Sterna fuscata*

During the two-day survey 40 to 50 Sooty Terns were flying low over the island in groups of 3 to 5 individuals. None were seen in the typical prebreeding swirls, and no evidence of previous attempts at nesting was found. Probably these terns were wandering individuals from nearby colonies, such as those on Caroline Atoll and Malden Island.
Specimens: 2 ♂♂, 1 ♀. USNM 495477, ♂, left testis 8x3 mm, wt. 159 g; USNM 495478, ♂, left testis 5x3 mm, wt. 183 g; USNM 495476, ♀, ovary 12x7 mm, largest ovum 4x4 mm, wt. 203 g.

BROWN NODDY (500 ± 100) *Anous stolidus*

On the east side of the island about 50 Brown Noddy nests were found in dense, shrubby *Pisonia*, at a height of 1.5 to 3 meters. Nests contained both eggs and young. Relatively few birds were seen by day, but numbers increased considerably at dusk when foraging birds returned from the ocean.
Specimen: USNM 495561, ♀, ovary 12x8 mm, largest ovum 2 mm, wt. 172 g.

BLACK NODDY (3,000 ± 1,000) *Anous tenuirostris*

Black Noddies nested in colonies throughout the forest at heights of 9 to 12 meters. An estimated 1,000 nests were present, containing eggs or young.
Specimens: 4 ♂♂, USNM 495580, testes 9x6 mm, wt. 98 g; USNM 495581, testes 6x3 mm, wt. 102 g; USNM 495582, testes 10x5 mm, wt. 100 g; USNM 495583, left testis 10x8 mm, wt. 106 g.

WHITE TERN (1,250 ± 750) *Gygis alba*

Although common throughout the forest, only a few White Terns were found nesting. Only eggs were found, all in trees; young birds may have been overlooked

One adult was banded.

Specimens: 2 ♂♂, 3 ♀♀. USNM 495604, ♂, rt testis 5x3 mm, wt. 118 g; USNM 495606, ♂, left testis 5x3 mm, wt. 108 g; USNM 495603, ♀, ovary 13x5 mm, wt. 110 g; USNM 495605, ♀, ovary 10x8 mm, largest ovum 4 mm, wt. 105 g; USNM 495607, ♀, ovary 7 mm, ova granular, wt. 105 g.

SUMMARY

During a visit to Vostok Island in June 1965 a POBSP field party found two species of vascular plants (*Pisonia grandis*, *Boerhavia repens*), one lizard (*Emoia cyanura*), one mammal (*Rattus exulans*), and twelve species of birds including nine central Pacific seabirds and three shorebirds.

Eight of the seabirds were breeding (Blue-faced, Brown, and Red-footed Boobies; Great and Lesser Frigatebirds; Brown and Black Noddies; and White Tern) while the remaining species (Sooty Tern) apparently was a visitor. The three shorebirds (Golden Plover, Bristle-thighed Curlew, Wandering Tattler) are migrants to the islands of the central Pacific.

The specific identities of the lizard and mammal are reported for the first time. Of the birds, only the Black Noddy has been reported previously.

ACKNOWLEDGEMENTS

Robert R. Fleet, Lawrence N. Huber, Charles R. Long, Dennis L. Stadel, and Robert S. Standen were members of the POBSP field party that surveyed Vostok. We are particularly indebted to Long who made detailed notes of the vegetation which we have used freely in this account. E. H. Bryan, Jr. was helpful in obtaining a manuscript dealing with Anderson's earlier visit to Vostok. We also thank the late Doris M. Cochran who identified the lizards, Ralph D. Kirkpatrick who commented on the mammal specimens, and A. Binion Amerson, Jr., Patrick J. Gould, Richard L. Zusi, and George E. Watson who read the manuscript and offered many helpful suggestions.

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Figure 2. Wind-sheared eastern edge of Pisonia forest, viewed from northeast, Boerhavia repens in left foreground (photo by C. R. Long, June 1965).

Figure 3. East side of island, viewed from north, showing Boerhavia repens covering coral gravel flat in foreground, blue-faced booby nesting colony in distance (photo by C. R. Long, June 1965).

Figure 4. Blue-faced booby with eggs, on coral gravel with Boerhavia repens (photo by R. S. Standen, June 1965).

ATOLL RESEARCH BULLETIN

No. 145

NOTES ON THE VASCULAR FLORA AND TERRESTRIAL VERTEBRATES OF CAROLINE ATOLL SOUTHERN LINE ISLANDS

by Roger B. Clapp and Fred C. Sibley

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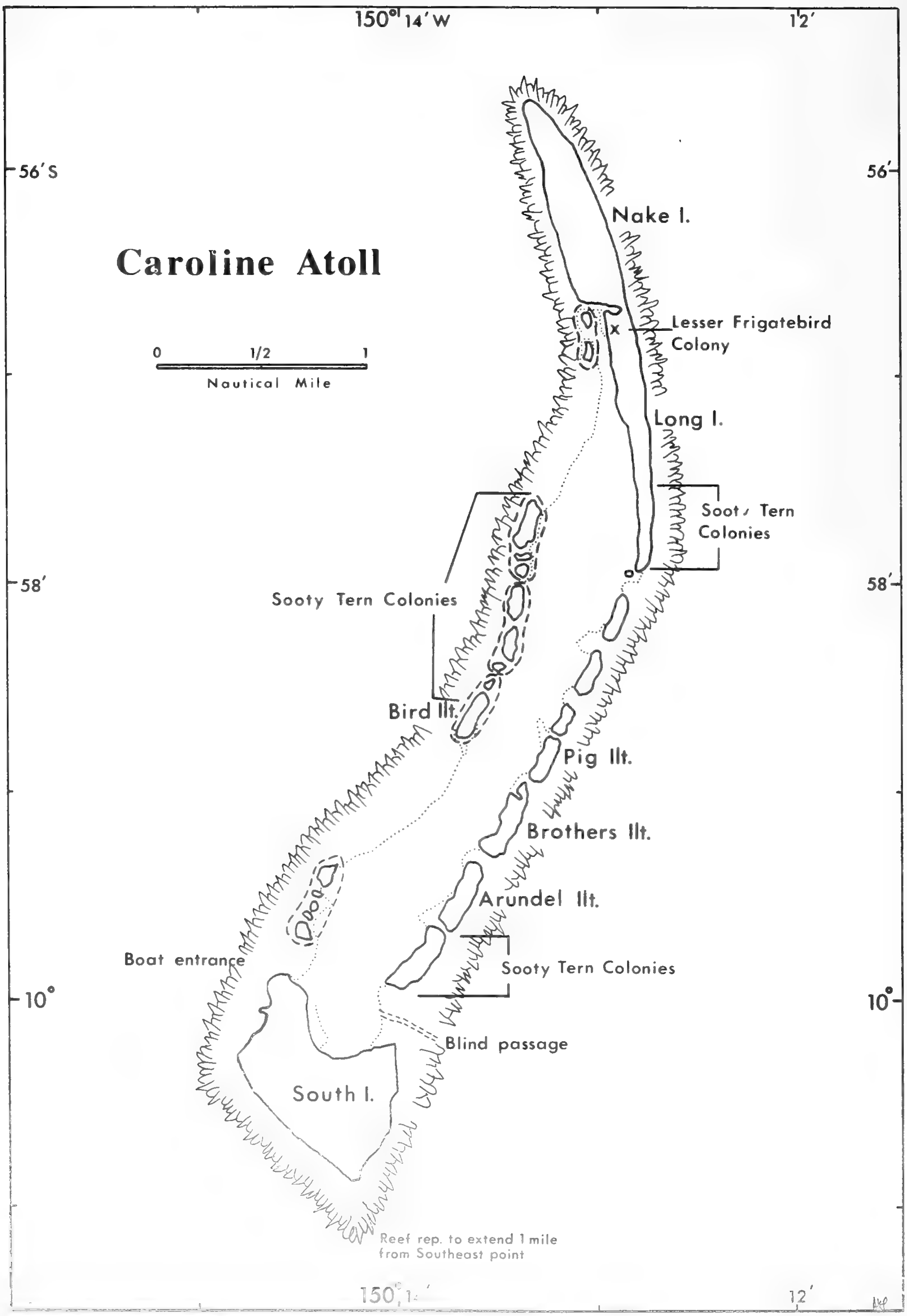

Figure 1. Map of Caroline Atoll. Modified from H. O. chart 928.

NOTES ON THE VASCULAR FLORA AND TERRESTRIAL VERTEBRATES OF CAROLINE ATOLL SOUTHERN LINE ISLANDS[1]

by Roger B. Clapp[2] and Fred C. Sibley[3]

From 0900 on 17 June to 0615 on 19 June 1965 Caroline Atoll was visited by a field party from the Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institution. The field party, led by Sibley, collected and made observations on vascular plants, fish, reptiles, mammals, and birds. All islands with the exception of the northern two-thirds of Nake were visited. Prior knowledge of the biota of Caroline Atoll is very scant, deriving almost entirely from the visits of F. D. Bennett in 1835, Devoy in 1875, and the U.S.S. Hartford in 1883. This paper summarizes earlier data and presents recent POBSP observations on the flora and terrestrial vertebrates, identifying many of them for the first time.

DESCRIPTION

Caroline is a low, densely vegetated, crescent-shaped coral atoll situated between 09°55' and 10°01' south latitude, and 150°14' and 150°13' west longitude. It is about 125 nautical miles east of Vostok Island and 125 miles northeast of Flint Island. The atoll is 5.75 miles long on the north-south axis, and attains a maximum breadth of 1.125 miles at the south end. Its area is ca. 942 acres and its circumference around the outer reef is about 13 miles (Holden and Qualtrough, 1884; Maude, 1953).

The central lagoon has much living coral, and coral heads break the surface. There are three large islands, Nake and Long to the north (conjoined on the east), and South to the south. Around the atoll rim and within the lagoon are small islets, many of which are unnamed (Figure 1). At low tide in 1965 there were 15 islets separated by water. Dry, unvegetated, flat areas of coral rock divide the islets, indicating that at one time over 25 separate islets may have existed.

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1. Paper No. 61, Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D. C.

2. Pacific Ocean Biological Survey Program, Smithsonian Institution.

3. Point Reyes Bird Observatory, Bolinas, California.

BRIEF HISTORY OF MAN'S ACTIVITIES ON CAROLINE ATOLL

Caroline Atoll was discovered by Pedro Fernandez de Quiros on 21 February 1606 (Maude, 1959). The atoll was subsequently sighted or visited by parties from a number of passing ships. It was visited on 16 December 1795 by the British sloop Providence, commanded by W. R. Broughton, who named the island Caroline after the daughter of Sir P. Stephens, First Lord of the British Admiralty. In 1821 it was sighted by Captain Thornton of the English whaler Supply for whom it received the alternate name Thornton (Bryan, 1942). It was visited 10 to 13 October 1825 by Hiram Paulding on the U.S. schooner Dolphin, and in 1828 by a Captain Stavers. On 23 April 1835 F. D. Bennett (1840) visited the atoll from the whaler Tuscan. In 1875 Caroline was visited by C. D. Voy, a naturalist from California who collected molluscs (Pilsbry and Vannatta, 1905a, 1905b) and fish (Fowler, 1899, 1901). From 21 April through 9 May 1883 a party from the U.S.S. Hartford was there to observe a total eclipse of the sun (Holden, 1884). During the visit observations and collections were made of plants (Trelease, 1884) and lepidoptera (Butler and Strecker, 1884), and very sketchy observations of terrestrial vertebrates and invertebrates were made by Dixon (1884).

Archaeological remains found on Caroline indicate that the atoll was occupied, possibly by people from the Tuamotus (Emory, 1947), prior to European exploration of the Pacific, but the first recorded occupancy began in 1846 when Collie and Lucett, a British firm, established a small native agricultural experiment there (N.I.D., 1943).

Between 1865 and 1872 Messrs. Brown and Brothers planted coconuts on the atoll and in July 1868 there were 27 human occupants. In 1872 the island was leased to Houlder Brothers and Company of London, and later, in 1881, to their manager, J. T. Arundel. Approximately 10,000 tons of guano were exported between 1873 and 1895. Coconut palms were planted during this period and copra was harvested in small quantities (Bryan, 1942; N.I.D., 1943).

Caroline was subsequently leased to Messrs. S. R. Maxwell and Company Ltd., a New Zealand firm, and was worked continuously as a coconut plantation from 1916 until 1934 when the company failed. Exports during the latter part of this period amounted to about 14 tons per annum. For a short time thereafter Caroline was worked as a coconut plantation by the administrator for the company's affairs. By 1936 only a few Tahitian families were still occupying the atoll (N.I.D., 1943).

The atoll was evidently seldom occupied, if at all, after 1 June 1943 when the occupation leases were cancelled and possession of the atoll reverted to the British Western High Pacific Commission (Maude, 1953).

VEGETATION

In 1825, Paulding (1831) noted that Caroline had "some trees of a large size upon it and in most places a thick growth of underwood" and further remarked that "a boat load of pepper-grass and pursley, of which there was a great abundance" was obtained. He only mentions seeing one coconut tree which, in light of Bennett's observations (see below), suggests that South Island was not visited.

Nearly ten years later Bennett (1840) made more detailed observations of the vegetation. He recorded ten flowering plants and a fern, introduced three other species, and related that Cocos were found only in a grove on the northeast side of South Island--a grove that covered about one-fifth of the land area of that island. Bennett stated that the atoll was "covered with verdure" and that "the interior of the island [was] a surface of sand, mingled with coral debris as well as with decayed vegetable and animal matters, which give it increasing fertility". He also mentioned trees "attaining the height of twenty feet" which may indicate that Cordia or Pisonia groves or both covered a more extensive area in the last century. Bennett stated that "the woodlands are chiefly composed of two species of Tournefortia" which we can only interpret as a reference to Cordia as well as Tournefortia. We have not been able to determine the present disposition of Bennett's plant collection, if indeed it still exists.

The only reasonably thorough collection of plants was made by W.S. Dixon during the visit of the U.S.S. Hartford. Many of the plant species collected or observed by Dixon were probably introduced during the earlier occupation of the island. Dixon's collections and observations (27 or 28 flowering plants, a fern, an alga, and a fungus) were subsequently reported by Trelease (1884). All plants, with the exception of Fleurya ruderalis, were collected on South Island.

Below is a short summary of the vegetation of each large island and of the islet groups as observed by the POBSP in 1965.

South Island. Old Cocos groves cover most of South Island. Interspersed with these groves are thickets of Morinda that are often associated with Ipomoea tuba. In some open areas where Cocos have died or fallen the grass Lepturus repens forms a nearly closed stand with Ipomoea. A Suriana-Lepturus zone forms a fringing association around the island. Suriana forms a dense continuous border of shrubs on the north side bordering the lagoon (Figure 2). On the other sides the Suriana shrubs are taller (to 2 m), less compact, and more scattered. Patches of Lepturus are scattered here and there and often extend well outside and beyond the Suriana zone towards the high-tide line. Individual trees of Pisonia grandis and Cordia subcordata were likewise scattered over the island.

Nake Island. On Nake, which had been planted to Cocos like South Island, groves extend the entire length of the island. The greater robustness of these Cocos groves, the occurrence of Psilotum, and the more frequent occurrence of Tacca, suggest that Nake received more precipitation than other portions of the atoll.

Associations of Pandanus, Morinda and Tournefortia occur in open areas of the interior and along the edge of the Cocos stands. Along the northeast side an almost continuous stand of Tournefortia borders the area between the Cocos groves and the open sandy beach with its scattered clumps of Lepturus and the ubiquitous Boerhavia repens. Some older Tournefortia trees were nearly 3 meters high. Tacca was found in scattered groups in damp muck areas under the Cocos groves. The only Tribulus observed on the entire atoll was found in an open sandy area among Tournefortia shrubs on the south end of the island.

Long Island. Clumps of Morinda and Cordia occur on the north end. Pisonia, Cordia and Suriana were also observed. On both sides of the island Tournefortia forms a fringe with open areas supporting associations of Lepturus, Boerhavia, and Portulaca (Figure 3).

Windward Islets. Small Cordia groves are present on most of these small eastern islets. Brothers Islet has a few Cocos trees. Suriana, forming a dense stand with Tournefortia, was found (to 3 m in height) on the islet just south of Arundel Islet. Tournefortia is also an important component on the other windward islets.

Leeward Islets. The vegetation on these islets is much sparser than on those on the windward side of the atoll. Pandanus occurs on the three small islets south on Nake Island. Further south lies an islet with a few Cocos trees and Pisonia. The other islets on the south have Cordia and Tournefortia with Lepturus, Fleurya, and Heliotropium. The Fleurya occupies small sand-filled niches in the exposed coral rubble while the Heliotropium is found in sand on the lagoon side of the islets.

The general aspect of the vegetation indicated a lengthy dry spell prior to our visit.

VASCULAR FLORA OF CAROLINE ATOLL

Vascular plants were collected by C. R. Long (POBSP) on 17 and 18 June. Herbarium specimens will be deposited in the herbarium of the University of Hawaii and some duplicates in the herbaria of the United States National Museum and the Bernice P. Bishop Museum.

In the following list collection numbers are those of Long's. Species not previously known to occur on the atoll are marked with an asterisk.

Psilotaceae

*_Psilotum nudum_ (L.) Beauv.
Found only on Nake I., common on wet base of _Cocos_, _Long_ _3233_.

Polypodiaceae

Polypodium scolopendria Burm. f.
Collected by Dixon and recorded by Bennett (as _Polypodium phymatodes_ L.). Ground cover under _Cocos_ forests on Nake I., _Long 3244_; under scattered _Cocos_ north end of Long I., _3250_; South I., _3287_. Apparently thriving even under very dry conditions.

Pandanaceae

Pandanus tectorius Park.
An unidentified _Pandanus_ was reported by Bennett and Trelease. Tree 2.5 m high at west edge of second islet south of Nake I., _Long 3227_. Also observed on Nake I.

Gramineae

Eleusine indica (L.) Gaertn.
Collected by Dixon. Not found by the POBSP.

Eragrostis tenella (Link) Beauv.
Collected by Dixon and reported by Trelease as _E. plumosa_ Lk. Not found by the POBSP.

Lepturus repens (Forst. f.) R. Br.
Collected by Dixon. Tufts to 1.5 dm high in coral sand, on second islet south of Long I., _Long 3211_; islet northeast of South I., _3221_; common growing in coral sand several meters above lagoon, Nake I., _3236_; exposed site in sand on east windward side of Nake I., _3238_; exposed site in sand, Long I., _3247_; near lagoon shore of west side of fourth islet north of Bird I., _3259_; numerous clumps under _Suriana_ on South I., _3286_.

Digitaria sp.
Collected by Dixon and recorded by Trelease as _Panicum_ (_Digitaria_) _marginata_ Lk.? C. R. Long who examined Dixon's specimen believes that it is a _Digitaria_ which may be identical to _Long 3235_.

Bromeliaceae

Ananas comosa L.
Collected by Dixon who found it cultivated on Caroline. Not found by the POBSP.

Palmae

Cocos nucifera L.
Reported as "cocoa-nut trees" by Bennett and identified as above by Dixon. Dry groves of South I., Long 3285. Extensive stands cover Nake and South Is.; a scattered number on north portion of Long I.

Liliaceae

Crinum sp.
An unidentified lily collected by Dixon and reported by Trelease was probably in this genus.

Taccaceae

Tacca leontopetaloides (L.) O. Ktze.
Introduced by Bennett but not found by Dixon. Occasionally in moist muck of South I., Long 3213; in fruit on South I., 3219; common under Cocos forest of Nake I., 3234. Numerous patches found in muck on the south end of Nake I.

Moraceae

Ficus carica L.
Collected by Dixon. An introduction cultivated for its fruit. Not found by the POBSP.

Urticaceae

Fleurya ruderalis (Forst. f.) Gaud. ex Wedd.
Reported by Bennett and collected by Dixon. Common in shady areas of South I., Long 3215; scattered on an exposed site in coral rubble and sand, second islet south of Nake I. (west side), 3229; under shade of Cocos and Pisonia on north side of Long I., 3253. Many seedlings observed on Long I.

Chenopodiaceae

Boussingaultia gracilis Miers forma pseudo-basseloides Hauman
Collected by Dixon and reported by Trelease as B. baseloides H. B. K. Trelease's comment that the specimen collected by Dixon was a "vine climbing over portico" suggests that it was introduced by residents of Caroline. Not found by the POBSP.

Nyctaginaceae

Boerhavia repens L.
Reported by Bennett as B. hirsuta and collected (as Boerhaavia, sp.?) by Dixon. Light purple flowers, second islet south of Long I.,

Long 3210; stems to 0.6 m long, large coriaceous leaves, red stems, islet northeast of South I., 3324; Nake I., 3239; stems to 0.5 m long, rooting at nodes, Nake I., 3225; north end of Long I., 3252; fourth islet north of Bird I., 3262; in shade, South I., 3289, 3291.

Pisonia grandis R. Br.
Collected by Dixon. Tree about 4 m high, north shore of South I., Long 3280. A small grove observed on the north end of Long I.

Portulacaceae

Portulaca lutea Sol.
Reported by Bennett. Trelease stated that Dixon recognized two varieties of Portulaca but neither was collected. Stems clumped, flowers yellow, islet northeast of South I., Long 3223; clumps 1.5 dm high, common in open coral and rubble, second islet south of Nake I., 3231; common on Nake I., 3237; common in gravel above lagoon shore on north end of Long I., 3255; fourth islet north of Bird I., 3257; common in exposed area on South I., 3292.

Cruciferae

Lepidium bidentatum Mont.
Collected by Dixon as L. piscidium Forst. Also reported by Bennett as a "Lepidium of luxuriant growth". Not found by the POBSP.

Leguminosae

Inocarpus fagiferus (Park.) Fosberg
Introduced by Bennett but not found subsequently.

Zygophyllaceae

*Tribulus cistoides L.
Stems to 0.8 m long in an open sandy area among Tournefortia shrubs on Long I., Long 3245. Not seen elsewhere on the atoll.

Surianaceae

Suriana maritima L.
Collected by Dixon. Shrub to 1.8 m high on east edge of islet northeast of South I., Long 3220.

Euphorbiaceae

Euphorbia pilulifera L.
Collected by Dixon. Not found by the POBSP.

Phyllanthus amarus Schum. and Thonn.
Collected by Dixon and recorded by Trelease as P. niruri L., Herb to 4 dm, common on the north side of South I., Long 3283.

Malvaceae

Sida fallax Walp.
Collected by Dixon who only found one specimen. Not found by the POBSP.

Guttiferae

Calophyllum inophyllum L.
Collected by Dixon but not found by the POBSP.

Caricaceae

Carica papaya L.
Collected by Dixon. An introduction not found by the POBSP.

Cucurbitaceae

Cucurbita pepo L.
"Recognized in cultivation" by Dixon but not found by the POBSP.

Convolvulaceae

*Ipomoea pes-caprae ssp. brasiliensis (L.) Van Ooststr.
Stems to 7 m long, in fruit, near copra shed, north shore, South I., Long 3281. Only one plant seen on the atoll.

Ipomoea batatas L.
Introduced by Bennett but not found subsequently.

*Ipomoea tuba (Schlecht.) G. Don
Trailing vine, white flowers, stems to 6 m long, common on South I., Long 3228; Nake I., 3242; trailing on Tournefortia at north end of Long I., 3251; stems to 25 m climbing over Morinda and Cocos on South I., 3293.

Boraginaceae

Cordia subcordata Lam.
Collected by Dixon. Tree to 4 m near lagoon, South I., Long 3213; tree to 3 m high in interior of islet in coral rubble about 15 meters above high tide line, west side of second islet south of Nake I., 3228; tree to 4.5 m high with orange flowers, common on interior of north end of Long I., 3246; fourth islet north of Bird I., 3261; tree to 4 m at edge of water along lagoon, north shore of South I., 3261.

Heliotropium anomalum H. and A.
Recorded (as Heliotropium curassavicum) by Bennett and collected by Dixon. In gravel of outer beach of islet northeast of South I., Long 3222; common in clumps to 1.2 dm high in exposed site in coral gravel on lagoon side of second islet south of Nake I. (west side), 3240; in gravel of lagoon shore, Long I., 3248; fourth islet north of Bird I., 3256; clumps to 2.8 dm high on coral gravel under Suriana on the southwest side of South I., 3288.

Tournefortia argentea L. f.
Probably seen by Bennett, and collected by Dixon. Small tree, with white flowers, 2.5 m high, edge of lagoon, South I., Long 3216; edge of islet northeast of South I., 3226; shrub 3 m high, above high-tide line, Nake I., 3241; Long I., 3249; common, fourth islet north of Bird I., 3258.

Scrophulariaceae

Russelia equisetiformis Schlecht.
Collected by Dixon as R. juncea Zucc. Trelease noted that it had been probably introduced. Not found by the POBSP.

Rubiaceae

Morinda citrifolia L.
Reported by Bennett and collected by Dixon. Small tree, 2 m high South I., Long 3214; young plant, 6 dm high, South I., 3217; shrub to 2.5 m, Nake I., 3232; common at edge of Pisonia forest north end of Long I., 3254; small tree to 3 m forming dense thickets, central area of South I., 3282.

TERRESTRIAL VERTEBRATES OTHER THAN BIRDS

"Small lizards" were reported in 1825 by Paulding (1831) but ten years later Bennett stated that he had seen no "lizards or other land amphibia." Dixon (1884) reported three species of lizards but did not identify them. Dixon also reported turtles (Chelonia mydas?) but noted they were not numerous.

Three species of lizards were found on the atoll by the POBSP and specimens were obtained of each: one Black Skink (Emoia nigra, USNM 158358), two Polynesian Geckos (Gehyra oceanica. USNM 158353-354), and three Mourning Geckos (Lepidodactylus lugubris, USNM 158355-357). No turtles were seen.

Domestic pigs were introduced by Captain Stavers in 1828 (Bryan, 1942) but none were present when Bennett visited the atoll seven years later. In 1848 several native families with "pigs, fowls, turkey, etc." were transported to Caroline by Edward Lucett (1851) and in 1868 the 27

persons living on the island were raising stock, pigs, and poultry (Bryan, 1942). No livestock were reported in 1883 by Dixon, nor were any found on the islands by the POBSP.

Rats were seen by both Bennett and Dixon. Bennett stated that the rats "were of a red-brown color," while Dixon noted that "the brown rat...is not numerous" and that "their nests were made in the cocoa-nut trees, just at the base of the fronds." The POBSP saw Polynesian Rats (Rattus exulans) on South Island and collected two (USNM 361450-451). USNM 361450 was a juvenile male weighing 19.3 grams and 361451 was a female weighing 53 grams. Measurements (in mm) of the total length, tail, hind foot, and ear for the two specimens were, respectively, 206, 106, 25, 15 and 270, 173, 30, 17. Rats were not common and were observed only on South.

OBSERVATIONS OF BIRDS

Few of the birds seen by Bennett and Dixon were identified to species but some were described in enough detail to allow an identification.

Bennett (1840) reported seven species: "a tree-nesting booby" (=Sula sula), "frigatebirds" (Fregata sp.?), "a coot" (?), "curlews" (=Numenius tahitiensis), "a species of Totanus, similar to that we found at Raitea, with the exception that its legs are lemon-color, while in the Raitean species they were blue" (perhaps Heteroscelus incanum, while the bird seen at Raitea may have been Pluvialis dominica), "a great number of small pigeons, with white head and neck, and the rest of their plumage a rich brown color" (probably Anous tenuirostris but possibly A. stolidus), and "small white terns" (=Gygis alba).

Dixon (1884) reported 12 species but specific identification is reasonably certain for only four: "plover" (P. dominica), "curlew" (N. tahitiensis), a heron that occurred in "two varieties, brown and white" (=Demigretta sacra), and "an all-white tern" (=G. alba). He also reported "snipes" (Heteroscelus or Arenaria?), two species of "seagull" (?), "the noddy" (Anous sp. ?), the "Frigate bird" (Fregata sp.) a "Gannet" and a "Booby" (probably Sula sula and Sula sp.?); he reported that a colleague had heard "the notes of a singing bird" (?). Arundel (1890) stated that "a pigeon" occurred on Caroline. This may have referred to Ducula but equally likely to Anous.

Thus, although a fairly wide variety of birds had been reported prior to the POBSP visit, specific identifications were reasonably certain for only five species: Red-footed Booby, Golden Plover, Bristle-thighed Curlew, Reef Heron, and White Tern.

In the following species accounts the numbers in parentheses following the species name are an estimate of the total number of flying birds, including breeding adults, nonbreeding adults, subadults and juveniles.

Following this figure is another which gives the estimated number of breeding birds.

These estimates are not very accurate since the brevity of the visit and the large number of islets visited precluded detailed census work. We present them because we feel that such estimates, although partly subjective, show relative abundance of the various species better than such words as "numerous", "common", or "scarce".

Annotated List

BLUE-FACED BOOBY (*ca* 10--at least 8 breeding birds) *Sula dactylatra*

POBSP personnel found two nests, one containing two eggs, the other a nestling, on the east side of Nake Island along the ocean beach. Navy personnel reported two other nests with eggs from the same area.

BROWN BOOBY (*ca* 15 ± 10% -- at least 8 breeding birds) *Sula leucogaster*

Three nests, two with eggs and one with a nestling, were found on Nake Island. Five to eight adults were seen roosting on emergent portions of the coral reef along the southeast passage between South Island and the islet south of Arundel Islet.

RED-FOOTED BOOBY (5,000 ± 25%--4,000 ± 25% breeding birds) *Sula sula*

Red-footed Boobies were found nesting on almost all islands except South. Nests were found on a wide variety of plants (*Cordia*, *Morinda*, *Pisonia*, and *Tournefortia*) and contained eggs and young, with the latter ranging in size from recently hatched young to near-fledging juveniles. Several other nests were found that had been recently lined with fresh *Pisonia* leaves, suggesting that some females had not yet laid. In late April, 1835 (Bennett, 1840) Red-footed Boobies were building nests or hatching eggs (i.e., incubating). No young were seen and all eggs examined were heavily incubated.
Specimens: 3♂♂, 2♀♀, 18 June 1965: USNM 495106, ♂ left testis 10 x 4 mm, weight 726 g; USNM 495108, ♂ testes 14 mm, wt. 692 g; USNM 495109, ♂ testes 14 x 7 mm, wt. 635 g; USNM 495105, ♀, ovary 10 mm, granular, wt. 790 g; USNM 495107, ♀, ovary 20 x 10 mm, wt. 837 g; (USNM 495105 with a nestling, and 495106 and 495107 were collected from eggs).

GREAT FRIGATEBIRD (10,000 ± 25%--8,000 ± 25% breeding birds) *Fregata minor*

Great Frigatebirds were found nesting on almost all islands. Both eggs and young were present. Nests are found in the same habitat utilized by Red-footed Boobies.
Specimens: 2 ♀♀, both collected from eggs, 18 June 1965: USNM 495092 ovary 18 x 10 mm, lg. ovum 4 x 4 mm, wt. 921 g; USNM 495093, lg. ovum 3 mm, wt. 1200 g.

LESSER FRIGATEBIRD (1,000 ± 10%, 400 ± 10% breeding birds) *Fregata ariel*

Lesser Frigatebirds nested only near the north end of Long Island (Figure 1) where a small colony of *ca* 400 birds had constructed nests in low *Morinda* bushes and in small *Cordia* trees, both of which were much overgrown by *Ipomoea tuba*. Only eggs were found in the nests, but flying immatures, presumably birds from a previous breeding season, were noted. Other frigatebirds were seen displaying and building nests.

GOLDEN PLOVER (30 ± 10%) *Pluvialis dominica*

Golden Plovers, like other shorebirds, were scarce but generally distributed throughout the coral reefs. They appeared, like other shorebirds, to be somewhat more abundant along the outer perimeter of the atoll.
Specimens: 18 June 1965: USNM 495722, ♂, testes 3 x 2mm, wt. 113 g.

BRISTLE-THIGHED CURLEW (20 ± 10%) *Numenius tahitiensis*

WANDERING TATTLER (70 ± 10%) *Heteroscelus incanum*

Specimens: 3 ♂♂, 18 June 1965: USNM 495726, testes 2 mm, wt. 102 g; USNM 495727, left testis 3 x 2 mm, wt. 101 g; USNM 495728, testes 3 x 2 mm, wt. 121 g.

RUDDY TURNSTONE (*ca* 5) *Arenaria interpres*

REEF HERON (40 ± 25%) *Demigretta sacra*

Most Reef Herons were seen foraging singly around the reefs but appeared more common along the interior lagoon. No nests were found but the size of the gonads of one specimen (USNM 495303) suggests that the species may breed there.

Of ten different individuals tabulated on 18 June, half were white morph, half dark morph. No mottled individuals were seen.
Specimens: 2♂♂, 1♀, 17 June 1965; 1♂, 18 June 1965: USNM 495301, ♂, testes 5 x 3 mm, wt. 522 g; USNM 495302, ♂, left testis 6 x 4 mm, wt. 540 g; USNM 495303, ♀, lg. ovum 10 mm, wt. 541 g; USNM 498280, ♂(skeleton).

SOOTY TERN (*ca* 500,000 ± 25%--*ca* 400,000 ± breeding birds) *Sterna fuscata*

Sooty Tern colonies were found on a number of the islets and several geographically discrete colonies were found on the same islet. In one instance colonies showed a discrete but small difference in their breeding cycles on the same island (Table 1). Most colonies contained incubated eggs to week-old chicks, indicating that peak eggs laying had occurred 2 to 5 weeks earlier (mid-late May).

Table 1. Sooty Tern Colonies on Caroline Atoll

Location of Colony	Approximate Number of Breeding Birds*	Breeding Status
Three groups of islets on west side of atoll just south of Nake I.	5,000	Eggs and small chicks
South half of Long I. (3 colonies)	100,000	Only downy young
	25,000	Eggs to week-old chicks
	20,000	Only eggs, most slightly incubated
Islet south of Arundel Islet (4 main colonies)	120,000	Eggs to week-old chicks (ca 20,000 eggs and 40,000 nestlings)
	10,000	Eggs to week-old chicks
	20,000	" "
	100,000	" "

*Most estimates determined by intensive banding or by estimating nesting density and colony area.

On most islands and on the islet south of Arundel, nests were located in the underbrush under stands of Tournefortia or other emergent vegetation or were in more open areas bordering such stands (Figure 5).

Considerable predation on eggs and nestlings by the coconut crab (Birgus latro) was noted in the colonies on the islet south of Arundel. Specimens: 1 ♂, 4 ♀♀, 17 June 1965: USNM 495481, ♂, rt. testis 7 x 5 mm, wt. 163 g; USNM 495479, ♀, ovary 11 x 5 mm, lg. ovum 2 x 2 mm, wt. 138 g; USNM 495480, ♀, ovary 10 mm, lg. ovum 1 mm, wt. 167 g; USNM 495482, ♀, ovary 10 x 7 mm, wt. 166 g; USNM 495483, ♀, ovary 10 x 7 mm, ova granular, wt. 159 g.

BROWN NODDY (1,000 ± 25%--800 ± 25% breeding birds) Anous stolidus

Nests contained both eggs and young.
Specimen: 17 June 1965: USNM 495562, ♂, testis 12 x 5 mm, wt. 150 g.

BLACK NODDY (7,000 ± 25%, 5,000 ± 25% breeding birds) *Anous tenuirostris*

Black Noddies were found nesting on most islands. The few nests examined contained eggs or young.

WHITE TERN (4,000 ± 25% -- several thousand breeding birds) *Gygis alba*

White Terns were found breeding on most islands. About half of the breeding birds were with eggs, and half with young.
Specimen: 18 June 1965: USNM 495608, ♀, largest ovum 1.5 mm, wt. 100 g.

BLUE-GRAY NODDY (*ca* 5) *Procelsterna cerulea*

Several Blue-gray Noddies were seen flying over the central lagoon and one of these was collected. No birds were seen on the ground and no nests were found.
Specimen: 18 June 1965: USNM 495540, ♀, ovary 7 x 9 mm, lg. ovum 2 mm, wt. 54.1 g (in heavy body molt).

SUMMARY

Observations and collections of the flora and vertebrate fauna made by the Pacific Ocean Biological Survey Program in June 1965 are reported herein.

Twenty species of plants were collected including 18 flowering plants, a fern, and a psilotum. Of these the psilotum (*Psilotum nudum*) and three flowering plants (*Tribulus cistoides*, *Ipomoea pes-caprae* ssp. *brasiliensis*, *Ipomoea tuba*) had not been previously reported from the atoll. Five other species were collected for the first time (*Pandanus tectorius*, *Cocos nucifera*, *Tacca leontopetaloides*, *Boerhavia repens*, *Portulaca lutea*). Many other species previously recorded from Caroline were not found. Most of these were introduced species (e.g., *Carica papaya*, *Curcurbita pepo*, *Ficus carica*) which probably did not survive the rigors of existence on the atoll.

Three species of lizards were collected and identified (*Emoia nigra*, *Gehyra oceanica*, and *Lepidodactylus lugubris*), none of which had been previously reported from the atoll but all of which are widespread in Polynesia. Polynesian Rats (*Rattus exulans*), which had not been previously identified to species, were also collected.

Fifteen species of birds were recorded. Four were migrant shorebirds (Golden Plover, Bristle-thighed Curlew, Wandering Tattler, Ruddy Turnstone) that occur commonly in the central Pacific. Reef Herons possibly breed on Caroline but may have wandered to the island from other breeding stations in the area. The remaining ten species are all seabirds that breed in the central Pacific. Of these, all were found breeding except the Blue-gray Noddy which is apparently only a visitor

to the atoll. Red-footed Boobies, Great and Lesser Frigatebirds, Sooty Terns, Brown and Black Noddies were all common to abundant, but Blue-faced and Brown Boobies were few in number.

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Figure 2. North side of South Island on lagoon. Note thick fringing stand of Suriana along high-water line. An occasional Pisonia or Cordia tree is found between the Suriana fringe and the Cocos forest.

Figure 3. East side of Long Island with Tournefortia fringe vegetation and scattered Suriana shrubs. Patches of Lepturus, Boerhavia, Portulaca association in foreground, Cocos to left.

Figure 4. North portion of Long Island as seen from the South Point of Nake Island. In the middle of Long Island are groves of <u>Cordia</u> and <u>Pisonia</u> with a dense fringing cover of <u>Tournefortia</u>

Figure 5. Sooty Tern colony among and under dense vegetation on Bird Islet.

ATOLL RESEARCH BULLETIN

No. 146

RECORDS OF MALLOPHAGA FROM PACIFIC BIRDS

by A. Binion Amerson, Jr. and K. C. Emerson

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RECORDS OF MALLOPHAGA FROM PACIFIC BIRDS[1]

by A. Binion Amerson, Jr.[2], and K. C. Emerson[3]

INTRODUCTION

The Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institution made 1,693 Mallophaga collections from 66 bird species on 25 islands and at sea in the Central, Northern and Southeastern Pacific from 1963 through 1969. This paper presents a listing of the hosts, the Mallophaga, and the collection localities.

The 66 host species belong to 5 orders and 13 families of sea, shore, and land birds. From these hosts were collected 96 Mallophaga species, belonging to 2 suborders, 2 families, and 26 genera.

Several sources were used in assembling the common and scientific names of the bird hosts. The names used in the American Ornithologists' Union's Checklist of North American Birds, 1957, 5th edition, were followed for species occurring in North America. Seabird names agree with those which appear in Watson (1966) and King (1967). Taxonomic order follows that of Peters (1931, 1934, and 1937) with the exception of the Procellariiformes, which follow Alexander *et al.* (1965), the Anseriformes, which follow Delacour (1954, 1959), and the Charadriiformes, which follow Bock (1958).

Mallophaga classification follows that of Hopkins and Clay (1952 and 1955), Emerson (1962, 1964a, and 1964b), and Ryan and Price (1969a and 1969b).

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PART I: HOST CHECKLIST

CENTRAL PACIFIC OCEAN

PROCELLARIIFORMES

Diomedeidae

Diomedea nigripes — Black-footed Albatross

Docophoroides pacificus ferrisi Harrison, 1937

Midway Atoll

Pacific Ocean, at sea:

21°05' N x 158°31' W	17°35' N x 167°14' W
20°50' N x 158°52' W	17°27' N x 167°24' W
20°48' N x 158°52' W	17°20' N x 164°12' W
20°23' N x 161°07' W	17°19' N x 167°40.5' W
20°00' N x 158°06' W	17°12.5' N x 167°55' W
19°28' N x 162°10.7' W	16°38' N x 169°38' W
19°19.5' N x 163°47.8' W	14°64'N x 169°44' W
19°11.7' N x 164°15' W	14°05' N x 170°11' W
18°54' N x 164°13' W	

Episbates pederiformis (Dufour, 1835)

Pacific Ocean, at sea:

21°05' N x 158°31' W	17°20' N x 164°12' W
20°50' N x 158°52' W	17°19' N x 167°40.5' W

Paraclisis confidens (Kellogg, 1899)

Midway Atoll

Pacific Ocean, at sea:

21°05' N x 158°31' W	17°27' N x 167°24' W
20°50' N x 158°52' W	17°20' N x 164°12' W
20°48' N x 158°52' W	17°19' N x 167°40.5' W
20°23' N x 161°07' W	17°12.5' N x 167°55' W
19°28' N x 162°10.7' W	17°12' N x 167°55' W
19°11.7' N x 164°15' W	16°38' N x 169°38' W
18°74' N x 146°31' W	14°46' N x 169°44' W
17°33' N x 167°14' W	14°05' N x 170°11' W

Procellariphaga affinis (Piaget, 1890)

Midway Atoll

Diomedea immutabilis — Laysan Albatross

Docophoroides pacificus subsp.

French Frigate Shoals, East Island

Kure Atoll, Green Island

Harrisoniella densa (Kellogg, 1896)

Kure Atoll, Green Island

Paraclisis giganticola (Kellogg, 1896)
Kure Atoll, Green Island

Perineus tenuipenalis Keler, 1958
Pacific Ocean, at sea:
10°19.5' N x 163°47.8' W

Procellariphaga affinis (Piaget, 1890)
Kure Atoll, Green Island

Procellariidae

Fulmarus glacialis — Fulmar
Perineus nigrolimbatus (Giebel, 1874)
Kure Atoll, Green Island

Pterodroma phaeopygia — Dark-rumped Petrel
Halipeurus noctivagus Timmermann, 1960
Pacific Ocean, at sea:
16°47' N x 172°13' W

Naubates pterodromi Bedford, 1930
Pacific Ocean, at sea:
16°47' N x 172°13' W

Pterodroma externa — White-necked Petrel
Ancistrona vagelli (J.C. Fabricius, 1787)
Pacific Ocean, at sea:
09°07' N x 150°34' W

Halipeurus kermadecense (Johnston and Harrison, 1912)
Pacific Ocean, at sea:

22°06' N x 151°00' W	14°19' N x 171°24' W
18°51' N x 151°00' W	14°04' N x 168°08' W
18°50' N x 151°00' W	13°53' N x 173°01' W
18°07' N x 166°02' W	12°20' N x 170°13' W
18°05' N x 151°00' W	09°00' N x 155°00' W
17°53' N x 151°00' W	08°54' N x 162°58' W
16°36' N x 171°21' W	08°29' N x 162°33' W
16°33' N x 171°55' W	08°12' N x 162°12' W
16°25' N x 171°31' W	

Procellariphaga sp.
Pacific Ocean, at sea:
18°07' N x 166°02' W

Naubates damma Timmermann, 1961
Pacific Ocean, at sea:

18°40' N x 151°00' W	09°07' N x 150°34' W
16°33' N x 170°55' W	09°00' N x 155°00' W
14°04' N x 168°08' W	

Trabeculus hexakon (Waterston, 1914)
Pacific Ocean, at sea:

18°50' N x 151°00' W	13°53' N x 173°01' W
18°07' N x 166°02' W	12°20' N x 170°13' W
17°53' N x 151°00' W	09°07' N x 150°34' W
16°36' N x 171°21' W	09°00' N x 155°00' W
16°33' N x 170°53' W	08°29' N x 162°33' W
14°32' N x 172°25' W	08°12' N x 162°12' W
14°04' N x 168°08' W	

Pterodroma rostrata — Tahiti Petrel

Ancistrona vagelli (J. C. Fabricius, 1787)
Pacific Ocean, at sea:
03°50' N x 178°09' E

Halipeurus marquesanus (Ferris, 1932)
Pacific Ocean, at sea:
03°50' N x 178°09' E

Pterodroma hypoleuca — Bonin Petrel

Halipeurus pelagicus (Denny, 1842)
Pacific Ocean, at sea:
15°38' N x 169°55' W

Halipeurus theresae Timmermann, 1969
Kure Atoll, Green Island
Pacific Ocean, at sea:

20°34' N x 160°13' W	15°06' N x 172°58' W
16°52' N x 168°50' W	14°19' N x 172°39' W
15°44' N x 172°20' W	14°05' N x 172°50' W
15°38' N x 169°55' W	07°18' N x 159°30' W

Procellariphaga enigki (Timmermann, 1963)
Kure Atoll, Green Island

Trabeculus hexakon (Waterston, 1914)
Kure Atoll, Green Island
Laysan Island
Pacific Ocean, at sea:

16°52' N x 168°50' W	15°06' N x 172°58' W
16°14' N x 171°51' W	14°05' N x 172°50' W

Pterodroma neglecta — Kermadec Petrel

Ancistrona vagelli (J. C. Fabricius, 1787)
Pacific Ocean, at sea:
09°00' N x 155°00' W

Halipeurus kermadecense (Johnston and Harrison, 1912)
Pacific Ocean, at sea:
13°54' N x 168°21' W

Trabeculus fuscoclypeatus (Johnston and Harrison, 1912)
Pacific Ocean, at sea:
13°54' N x 168°21' W

Pterodroma alba — Phoenix Petrel

Halipeurus heraldicus Timmermann, 1960
Christmas Atoll, Motu Upua Island
Johnston Atoll, Sand Island
Phoenix Island

Procellariphaga sp.
Johnston Atoll, Sand Island

Trabeculus hexakon (Waterston, 1914)
Phoenix Island

Pterodroma cooki cooki — Cook's Petrel

Halipeurus leucophryna Timmermann, 1960
Pacific Ocean, at sea:
18°42' N x 164°39' W
16°59' N x 164°07' W
16°42' N x 172°36' W
14°12' N x 169°08' W
13°46' N x 172°56' W
13°30' N x 165°06' W
13°18' N x 170°09' W
09°00' N x 155°00' W

Halipeurus pelagicus (Denny, 1842)
Pacific Ocean, at sea:
06°04' N x 154°56' W

Trabeculus hexakon (Waterston, 1914)
Pacific Ocean, at sea:
18°42' N x 164°39' W
16°59' N x 164°07' W
16°42' N x 172°36' W
13°30' N x 165°06' W
12°31' N x 166°18' W
09°00' N x 155°00' W

Longimenopon sp.
Pacific Ocean, at sea:
16°14' N x 154°56' W

Bulweria bulwerii — Bulwer's Petrel

Halipeurus bulweriae Timmermann, 1960
Phoenix Island
Pacific Ocean, at sea:
20°06' N x 161°52' W
20°00' N x 162°19' W
19°52' N x 162°47' W

<u>Puffinus carneipes</u> Pale-footed Shearwater

<u>Naubates harrisoni</u> Bedford, 1930

Pacific Ocean, at sea:

17°28' N x 170°31' W

<u>Puffinus pacificus</u> Wedge-tailed Shearwater

<u>Ancistrona vagelli</u> (J. C. Fabricius, 1787)

Kure Atoll, Green Island

Pacific Ocean, at sea:

13°30' N x 168°21' W

06°37' N x 152°49' W

06°35' N x 152°54' W

<u>Halipeurus mirabilis</u> Thompson, 1940

Johnston Atoll, Sand Island

Kure Atoll, Green Island

Phoenix Island

Pacific Ocean, at sea:

23°24' N x 166°25' W	15°12' N x 174°01' W
23°20' N x 174°25' W	14°31' N x 170°17' W
22°13' N x 165°33' W	14°30' N x 170°15' W
22°09' N x 165°01' W	14°29' N x 173°45' W
21°35' N x 164°42' W	14°18' N x 171°23' W
20°49' N x 173°19' W	14°16.3' N x 170°15' W
20°34' N x 173°09' W	14°13' N x 170°17' W
20°28' N x 160°49' W	14°05' N x 172°50' W
19°49' N x 161°47' W	13°46' N x 172°59' W
19°41' N x 162°06' W	11°50' N x 166°28' W
19°40' N x 159°23' W	11°14' N x 165°29' W
19°34' N x 162°04' W	08°54' N x 162°58' W
19°32' N x 162°18' W	07°28' N x 160°07' W
19°10' N x 170°55' W	07°24' N x 159°52' W
19°10' N x 170°12' W	07°18' N x 159°30' W
18°07' N x 166°02' W	06°37' N x 152°49' W
17°05' N x 168°55' W	06°35' N x 152°54' W
16°50' N x 170°20' W	06°25' N x 169°21' W
16°20' N x 171°45' W	06°20' N x 153°14' W
16°13' N x 171°55' W	06°11' N x 155°20' W
16°11' N x 171°57' W	

<u>Procellariphaga paulula</u> (Kellogg and Chapman, 1899)

Johnston Atoll, Sand Island

Pacific Ocean, at sea:

06°35' N x 152°54' W

<u>Naubates harrisoni</u> Bedford, 1930

Johnston Atoll, Sand Island

Kure Atoll, Green Island

Phoenix Island

Pacific Ocean, at sea:

22°24' N x 163°17' W

21°01' N x 158°41' W

20°49' N x 173°19' W	14°52' N x 172°15' W
20°34' N x 173°09' W	14°31' N x 170°17' W
19°49' N x 161°47' W	14°30' N x 170°15' W
19°40' N x 159°00' W	14°29' N x 173°45' W
19°35' N x 162°22.5' W	14°05' N x 172°50' W
19°34' N x 162°04' W	12°49' N x 170°24' W
19°32' N x 162°18' W	11°53' N x 157°00' W
19°27' N x 162°36' W	11°50' N x 166°28' W
19°20' N x 162°58' W	11°14' N x 165°29' W
18°38' N x 164°55' W	10°18' N x 173°00' W
18°07' N x 166°02' W	08°54' N x 162°58' W
16°50' N x 170°20' W	07°28' N x 160°07' W
16°20' N x 171°45' W	07°24' N x 159°52' W
15°45' N x 160°12' W	06°35' N x 152°54' W
15°12' N x 174°01' W	06°20' N x 153°14' W

Saemundssonia puellula Timmermann, 1965
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Pacific Ocean, at sea:

23°20' N x 174°25' W	19°35' N x 162°27.5' W
22°52' N x 157°00' W	19°10' N x 170°12' W
22°13' N x 165°33' W	16°20' N x 171°45' W
20°49' N x 173°19' W	14°29' N x 173°45' W
20°43' N x 173°15' W	13°46' N x 172°59' W
20°34' N x 173°09' W	10°22' N x 173°42' W
19°49' N x 161°47' W	07°18' N x 159°30' W
19°40' N x 159°23' W	06°11' N x 155°20' W
19°35' N x 162°22.5' W	

Trabeculus hexakon (Waterston, 1914)
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Pacific Ocean, at sea:

21°35' N x 164°42' W	14°31' N x 170°17' W
20°49' N x 173°19' W	14°30' N x 170°15' W
20°34' N x 173°09' W	14°16.3' N x 170°15' W
19°49' N x 161°47' W	14°05' N x 172°50' W
19°40' N x 159°23' W	12°49' N x 170°24' W
19°34' N x 162°04' W	11°34' N x 170°43' W
19°32' N x 162°18' W	11°50' N x 166°28' W
18°38' N x 164°55' W	08°54' N x 162°58' W
18°07' N x 166°02' W	07°28' N x 160°07' W
16°50' N x 170°20' W	07°24' N x 169°52' W
16°20' N x 171°45' W	06°37' N x 152°49' W
15°45.9' N x 169°12' W	06°35' N x 152°54' W
15°32' N x 170°04' W	06°25' N x 169°21' W
15°12' N x 174°01' W	06°20' N x 153°14' W

Puffinus griseus — Sooty Shearwater

Halipeurus diversus (Kellogg, 1896)
Pacific Ocean, at sea:
02°35' N x 174°34' W — 03°10' S x 178°45' W
02°32' N x 174°42' W

Procellariphaga paulula (Kellogg and Chapman, 1899)
Pacific Ocean, at sea:
02°35' N x 174°34' W — 03°10' S x 178°45' W
02°32' N x 174°42' W

Trabeculus hexakon (Waterston, 1914)
Pacific Ocean, at sea:
02°35' N x 174°34' W — 02°32' N x 174°42' W

Puffinus tenuirostris — Slender-billed Shearwater

Halipeurus diversus (Kellogg, 1896)
Pacific Ocean, at sea:
11°31' N x 171°26' W

Trabeculus hexakon (Waterston, 1914)
Pacific Ocean, at sea:
12°03' N x 170°36' W — 11°26' N x 171°26' W
11°31' N x 171°17' W

Puffinus nativitatis — Christmas Shearwater

Halipeurus spadix Timmermann, 1961
Christmas Atoll, Motu Upua Island
Midway Atoll
Phoenix Island
Pacific Ocean, at sea:
06°41' N x 152°45' W

Naubates harrisoni Bedford, 1930
Wake Atoll

Trabeculus hexakon (Waterston, 1914)
Phoenix Island
Wake Atoll

Puffinus puffinus newelli — Newell's Shearwater

Halipeurus diversus (Kellogg, 1896)
Pacific Ocean, at sea:
20°36' N x 160°05' W

Trabeculus aviator (Evans, 1912)
Pacific Ocean, at sea:
10°41' N x 149°16' W

Puffinus lherminieri — Audubon's Shearwater

Halipeurus spadix Timmermann, 1961
Canton Atoll
Phoenix Island

Hydrobatidae

<u>Oceanodroma castro</u> — Harcourt's Storm Petrel

<u>Halipeurus pelagicus</u> (Denny, 1842)

Pacific Ocean, at sea:
19°49' N x 159°59' W

<u>Nesofregetta albigularis</u> — White-throated Storm Petrel

<u>Halipeurus nesofregettae</u> Timmermann, 1961

Christmas Atoll
Phoenix Island

<u>Saemundssonia</u> sp.

Phoenix Island

PELECANIFORMES

Phaethontidae

<u>Phaethon rubricauda</u> — Red-tailed Tropicbird

<u>Austromenopon</u> sp.

Christmas Atoll, Motu Upua Island
Pacific Ocean, at sea:

14°34' N x 172°32' W	13°40' N x 172°49' W
14°27' N x 171°23' W	12°09' N x 171°20' W

<u>Saemundssonia hexagona</u> (Giebel, 1874)

Enderbury Island
Howland Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Pacific Ocean, at sea:

22°35' N x 163°48' W	14°34' N x 172°32' W
15°25' N x 170°20' W	14°32' N x 171°15' W
15°23' N x 172°47' W	14°22' N x 172°36' W
15°18' N x 173°56' W	13°58' N x 170°47' W
15°06' N x 169°33.5' W	13°26' N x 170°08' W
14°41' N x 172°26' W	12°09' N x 171°20' W

<u>Phaethon lepturus</u> — White-tailed Tropicbird

<u>Austromenopon miloni</u> (Seguy, 1949)

Pacific Ocean, at sea:

18°22' N x 165°43' W	15°20' N x 170°30' W
17°22' N x 167°54' W	14°47' N x 170°50' W

<u>Saemundssonia uppaluensis</u> (Rudow, 1870)
Pacific Ocean, at sea:

19°44' N x 171°57' W	14°57' N x 170°37' W
19°15' N x 170°05' W	14°25' N x 172°31' W
16°02' N x 171°57' W	09°00' N x 155°00' W
15°24' N x 173°54' W	

Pelecanidae

<u>Sula dactylatra</u> — Blue-faced Booby

<u>Eidmanniella albescens</u> (Piaget, 1880)
Enderbury Island
Howland Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Kwajalein Atoll
Pacific Ocean, at sea:

16°31' N x 171°29' W	08°35' N x 153°28' W
13°45' N x 169°33' W	08°28' N x 160°07' W
13°24' N x 171°41' W	08°28' N x 153°35' W
10°09' N x 167°54' W	08°07' N x 153°37' W
08°52' N x 150°47' W	06°45' N x 152°43' W
08°47' N x 152°27' W	06°11' N x 155°21' W
08°36' N x 151°00' W	

<u>Pectinopygus annulatus</u> (Piaget, 1880)
Vostok Island
Pacific Ocean, at sea:

19°29' N x 163°32' W	14°11' N x 169°06.5' W
18°38' N x 166°51' W	13°47' N x 173°05' W
17°25' N x 168°21.5' W	13°24' N x 171°41' W
17°03' N x 169°07' W	10°44' N x 149°14' W
16°54' N x 171°25' W	10°09' N x 167°54' W
16°41' N x 169°24' W	09°30' N x 151°43' W
16°31' N x 169°33' W	08°56' N x 152°17' W
16°28' N x 171°10' W	08°47' N x 152°27' W
16°15' N x 169°39' W	08°35' N x 153°28' W
15°25' N x 173°54' W	08°28' N x 153°35' W
15°20' N x 170°24' W	08°09' N x 153°48' W
14°33' N x 170°06' W	08°07' N x 153°37' W
14°14' N x 172°43' W	07°28' N x 160°07' W

<u>Pectinopygus sulae</u> (Rudow, 1869)
Kure Atoll, Green Island
Pacific Ocean, at sea:

14°58' N x 170°10' W	06°35' N x 152°54' W
10°44' N x 149°14' W	06°11' N x 155°21' W
08°52' N x 150°47' W	

<u>Sula sula</u> Red-footed Booby

<u>Eidmanniella albescens</u> (Piaget, 1880)

Pacific Ocean, at sea:

16°50' N x 169°15' W	16°33' N x 170°59' W
16°45' N x 169°00' W	12°22' N x 171°01' W

<u>Pectinopygus sulae</u> (Rudow, 1869)

Howland Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Vostok Island
Pacific Ocean, at sea:

21°01' N x 158°41' W	16°15' N x 171°14' W
20°55' N x 160°21' W	16°07' N x 169°18' W
20°17' N x 160°55' W	16°06' N x 169°32.5' W
17°49' N x 163°30' W	15°54' N x 172°08' W
17°15' N x 164°14' W	15°06' N x 170°31' W
17°09' N x 169°10' W	14°59' N x 169°35' W
16°54' N x 169°21' W	14°51.5' N x 169°49' W
16°50' N x 171°14' W	14°26' N x 169°04' W
16°50' N x 169°15' W	14°23' N x 171°07' W
16°45' N x 169°00' W	13°30' N x 160°38' W
16°43' N x 171°17' W	13°14' N x 169°58' W
16°38' N x 169°38' W	12°22' N x 171°01' W
16°33' N x 170°59' W	

<u>Sula leucogaster</u> Brown Booby

<u>Eidmanniella albescens</u> (Piaget, 1880)

Erikub Atoll

<u>Pectinopygus sulae</u> (Rudow, 1869)

Erikub Atoll

Fregatidae

<u>Fregata minor</u> Great Frigatebird

<u>Colpocephalum angulaticeps</u> Piaget, 1880

Johnston Atoll, Sand Island
Kure Atoll, Green Island
Phoenix Island
Pacific Ocean, at sea:
14°20' N x 171°21' W

<u>Fregatiella aurifasciata</u> (Kellogg, 1899)

Phoenix Island
Pacific Ocean, at sea:
16°55' N x 169°24' W

Pectinopygus gracilicornis (Piaget, 1880)
Enderbury Island
French Frigate Shoals, East Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Phoenix Island
Vostok Island
Pacific Ocean, at sea:
22°07' N x 165°02' W
16°55' N x 169°24' W
16°11' N x 171°53.5' W
14°20' N x 171°21' W
13°34' N x 169°55' W

Fregata ariel — Lesser Frigatebird
Pectinopygus sp.
Howland Island
Phoenix Island
Tongareva Atoll

ANSERIFORMES

Anatidae

Anas crecca carolinensis — Green-winged Teal
Trinoton querquedulae (Linnaeus, 1758)
Midway Atoll

Anas penelope — European Widgeon
Trinoton querquedulae (Linnaeus, 1758)
Kure Atoll, Green Island

Anas acuta — Pintail
Anaticola crassicornis dafilensis Carriker, 1956
Kwajalein Atoll

Anatoecus dentatus subsp.
Kure Atoll, Green Island

Anatoecus sp.
Kwajalein Atoll

Holomenopon clypeilargum Eichler, 1943 (?)
Kwajalein Atoll

Trinoton querquedulae (Linnaeus, 1758)
Kure Atoll, Green Island
Kwajalein Atoll
Midway Atoll

Anas querquedula Garganey Teal

Anatoecus sp.
Wake Atoll

Trinoton querquedulae (Linnaeus, 1758)
Midway Atoll
Wake Atoll

Anas clypeata Shoveler

Anaticola crassicornis hopkinsi Eichler, 1954
Wake Atoll

Aythya fuligula Tufted Duck

Anatoecus sp.
Midway Atoll

Trinoton querquedulae (Linnaeus, 1758)
Midway Atoll

CHARADRIIFORMES

Charadriidae

Squatarola squatarola Black-bellied Plover

Austromenopon squatarolae Timmermann, 1954
Johnston Atoll, Sand Island

Quadraceps charadrii hospes (Nitzsch, 1866)
Johnston Atoll, Sand Island

Pluvialis dominica Golden Plover

Actornithophilus ochraceus (Nitzsch, 1818)
Kure Atoll, Green Island
Wilder Shoal
Pacific Ocean, at sea:
18°36' N x 164°31' W

Quadraceps charadrii orarius (Kellogg, 1896)
Kure Atoll, Green Island
Pacific Ocean, at sea:
18°36' N x 164°31' W

Saemundssonia conica conica (Denny, 1842)
Kure Atoll, Green Island
Pacific Ocean, at sea:
18°36' N x 164°31' W

Scolopacidae

Numenius phaeopus — Whimbrel

Actornithophilus ocellatus (Rudow, 1869)
Maiana Atoll

Numenius tahitiensis — Bristle-thighed Curlew

Austromenopon phaeopodis (Schrank, 1802)
Pacific Ocean, at sea:
16°55' N x 170°20' W

Lunaceps numenii hopkinsi Timmermann, 1954
Kure Atoll, Green Island
Midway Atoll, Sand Island
Vostok Island
Pacific Ocean, at sea:
16°55' N x 169°32' W

Saemundssonia scolopacisphaeopodis (Schrank, 1803)
Midway Atoll, Sand Island

Limosa lapponica — Bar-tailed Godwit

Actornithophilus limosae (Kellogg, 1908)
Kwajalein Atoll
Lisianski Island

Saemundssonia limosae (Denny, 1842)
Lisianski Island

Totanus flavipes — Lesser Yellowlegs

Quadraceps falcigerus (Peters, 1931)
Kure Atoll, Green Island

Tringa glareola — Wood Sandpiper

Quadraceps obscurus (Burmeister, 1838)
Midway Atoll

Heteroscelus incanum — Wandering Tattler

Actornithophilus kilauensis (Kellogg and Chapman, 1902)
Aranuka Atoll
Kwajalein Atoll

Quadraceps impar Hopkins and Timmermann, 1954
Johnston Atoll, Sand Island

Arenaria interpres — Ruddy Turnstone

Actornithophilus bicolor (Piaget, 1880)
Kure Atoll, Green Island
Kwajalein Atoll
Pacific Ocean, at sea:
15°18' N x 171°40' W   12°30' N x 171°32' W

Actornithophilus pediculoides (Mjoberg, 1910)
Kwajalein Atoll

Austromenopon sp.
Pacific Ocean, at sea:
15°18' N x 171°40' W

Quadraceps strepsilaris (Denny, 1842)
Hull Island
Kure Atoll, Green Island
Pacific Ocean, at sea:
14°24' N x 172°40' W

Crocethia alba — Sanderling
Actornithophilus umbrinus (Burmeister, 1838)
Baker Island
Kwajalein Atoll

Carduiceps zonarius (Nitzsch, 1866)
Baker Island

Erolia melanotos — Pectoral Sandpiper
Actornithophilus umbrinus (Burmeister, 1838)
Taka Atoll

Erolia acuminata — Sharp-tailed Sandpiper
Actornithophilus umbrinus (Burmeister, 1838)
Kure Atoll, Green Island
Midway Atoll

Carduiceps zonarius (Nitzsch, 1866)
Gardner Island
Kure Atoll, Green Island
Midway Atoll

Lunaceps sp.
Kure Atoll, Green Island

Saemundssonia platygaster subsp.
Wake Atoll

Saemundssonia tringae (O. Fabricius, 1780)
Gardner Island

Stercorariidae

Stercorarius pomarinus — Pomarine Jaeger
Saemundssonia euryrhyncha (Giebel, 1874)
Pacific Ocean, at sea:
21°05' N x 158°31' W

Stercorarius longicaudus Long-tailed Jaeger

Quadraceps normifer parvopallidus (Eichler, 1951)
Pacific Ocean, at sea:
14°14' N x 169°13' W

Laridae

Larus atricilla Laughing Gull

Austromenopon transversum (Denny, 1842)
Pacific Ocean, at sea:
12°41' N x 171°28' W

Saemundssonia lari atricilla Carriker, 1956
Pacific Ocean, at sea:
12°41' N x 171°28' W

Sterna sumatrana Black-naped Tern

Austromenopon astrofulvum (Piaget, 1880)
Erikub Atoll

Sterna lunata Gray-backed Tern

Actornithophilus piceus piceus (Denny, 1842)
Hull Island
Wake Atoll

Austromenopon atrofulvum (Piaget, 1880)
Wake Atoll

Quadraceps sp.
Johnston Atoll, Sand Island
Phoenix Island

Saemundssonia snyderi (Kellogg and Paine, 1910)
Canton Atoll, Spam Island
Howland Island
Hull Island
Phoenix Island
Wake Atoll

Sterna fuscata Sooty Tern

Actornithophilus piceus piceus (Denny, 1842)
Enderbury Island
Johnston Atoll, Sand Island
Starbuck Island
Wake Atoll
Pacific Ocean, at sea:
14°16' N x 171°21' W

Austromenopon atrofulvum (Piaget, 1880)
Howland Island
Johnston Atoll, Sand Island
Phoenix Island
Wake Atoll

Quadraceps birostris (Giebel, 1874)
Canton Atoll, Spam Island
Enderbury Island
Pearl and Hermes Reef
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Phoenix Island
Wake Atoll
Pacific Ocean, at sea:
23°43' N x 174°33' W
23°25' N x 166°25' W
23°24' N x 166°25' W
22°28' N x 167°19' W
21°10' N x 161°20' W
20°29' N x 169°02' W
20°26' N x 161°02' W
20°25' N x 160°45.2' W
20°22.8' N x 160°51.2' W
20°21' N x 169°09' W
20°07.5' N x 161°14.8' W
20°05' N x 161°40' W
19°50' N x 163°04' W
19°40' N x 159°23' W
19°27' N x 169°53' W
18°45' N x 164°52' W
18°18' N x 171°60' W
18°10' N x 166°13' W
18°07' N x 166°02' W
18°03' N x 166°33' W
17°38' N x 171°55' W
16°57' N x 169°39' W
16°54' N x 171°35' W
16°50' N x 170°02' W
16°50' N x 169°56' W
16°50' N x 169°15' W
16°36' N x 171°12' W
16°20' N x 171°39' W
16°20' N x 171°19.5' W
16°19' N x 172°38.8' W
15°22' N x 170°14' W
15°10' N x 171°55' W
15°02' N x 168°56' W
14°16.3' N x 170°15' W
14°16' N x 171°21' W
12°51' N x 170°31' W
07°07' N x 158°54' W
06°22' N x 156°13' W
06°11' N x 155°20' W

Saemundssonia albemarlensis (Kellogg and Kuwana, 1902)
Canton Atoll, Spam Island
Enderbury Island
Hull Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Pearl and Hermes Reef
Phoenix Island
Wake Atoll
Pacific Ocean, at sea:
23°43' N x 174°33' W
23°25' N x 166°25' W
22°31' N x 176°16' W
22°28' N x 167°19' W
21°41' N x 173°13' W
20°37' N x 168°58' W
20°26' N x 161°02' W
20°25' N x 160°45.2' W
20°21' N x 169°09' W
20°05' N x 161°40' W

19°40' N x 159°23' W
18°45' N x 164°52' W
18°03' N x 166°33' W
17°38' N x 171°55' W
16°57' N x 169°39' W
16°54' N x 171°35' W
16°50' N x 170°02' W
16°50' N x 169°56' W
16°50' N x 169°15' W
16°49' N x 169°05' W
16°36' N x 171°12' W
16°20' N x 171°39' W
16°20' N x 171°19.5' W
16°20' N x 170°43' W
15°45.9' N x 169°12' W
15°10' N x 171°55' W
15°04' N x 174°20' W
15°02' N x 168°56' W
14°16.3' N x 170°15' W
12°15' N x 170°31' W
06°22' N x 156°13' W
06°11' N x 155°20' W

Thalasseus bergii — Crested Tern
Saemundssonia sp.
Jaluit Atoll

Procelsterna cerulea — Blue-gray Noddy
Austromenopon sp.
Phoenix Island

Quadraceps sp.
Phoenix Island

Anous stolidus — Brown Noddy
Actornithophilus incisus (Piaget, 1880)
Baker Island
Erikub Atoll
Hull Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Kwajalein Atoll
Palmyra Island
Phoenix Island
Tongareva Atoll

Actornithophilus sp.
Johnston Atoll, Sand Island

Austromenopon sp.
Kure Atoll, Green Island
Tongareva Atoll

Quadraceps separatus (Kellogg and Kuwana, 1902)
Hull Island
Johnston Atoll, Sand Island
Kure Atoll, Green Island
Kwajalein Atoll
Palmyra Island
Phoenix Island
Tongareva Atoll

<u>Saemundssonia lobaticeps remota</u> Timmermann, 1951
Kure Atoll, Green Island

<u>Anous tenuirostris</u> Black Noddy
<u>Actornithophilus ceruleus</u> Timmermann, 1954 (?)
Hull Island
Kure Atoll, Green Island
Vostok Island

<u>Actornithophilus incisus</u> (Piaget, 1880)
Christmas Atoll, Motu Upua Island

<u>Austromenopon</u> sp.
Hull Island

<u>Quadraceps hopkinsi</u> Timmermann, 1952
Christmas Atoll, Motu Upua Island
Hull Island
Vostok Island

<u>Gygis alba</u> White Tern
<u>Actornithophilus</u> sp.
Aranuka Atoll

<u>Saemundssonia</u> sp.
Christmas Atoll, Motu Upua Island
Kure Atoll, Green Island
Phoenix Island
Pacific Ocean, at sea:
16°01' N x 169°17' W

<u>NORTH PACIFIC OCEAN</u>

ANSERIFORMES

Anatidae

<u>Anas crecca carolinensis</u> Green-winged Teal
<u>Anatoecus</u> sp.
Aleutian Islands, Ananiuliak Island

CHARADRIIFORMES

Scolopacidae

Numenius phaeopus — Whimbrel

Austromenopon phaeopodis (Schrank, 1802)
Alaska, St. George Island

Lunaceps numenii phaeopi (Denny, 1842)
Alaska, St. George Island

Saemundssonia scolopacisphaeopodis (Schrank, 1803)
Alaska, St. George Island

Arenaria interpres — Ruddy Turnstone

Actornithophilus bicolor (Piaget, 1880)
Alaska, St. George Island

Quadraceps strepsilaris (Denny, 1842)
Alaska, St. George Island

Limnodromus scolopaceus — Long-billed Dowitcher

Carduiceps cingulatus (Denny, 1842) (?)
Alaska, St. George Island

Ereunetes mauri — Western Sandpiper

Carduiceps zonarius (Nitzsch, 1866)
Alaska, St. George Island

Lunaceps holophaeus cabanisi Timmermann, 1954
Alaska, St. George Island

Saemundssonia tringae (O. Fabricius, 1780)
Alaska, St. George Island

Erolia ptilocnemis — Rock Sandpiper

Carduiceps meinertzhageni Timmermann, 1954
Alaska, St. George Island

Lunaceps sp.
Alaska, St. George Island

Saemundssonia tringae (O. Fabricius, 1780)
Alaska, St. George Island

Erolia melanotos — Pectoral Sandpiper

Carduiceps zonarius (Nitzsch, 1866)
Alaska, St. George Island

Erolia acuminata — Sharp-tailed Sandpiper

Lunaceps sp.
Alaska, St. George Island

Philomachus pugnax — Ruff

Carduiceps scalaris (Piaget, 1880)
Alaska, St. George Island

Lunaceps holophaeus holophaeus (Burmeister, 1838)
Alaska, St. George Island

Laridae

Larus glaucescens — Glaucous-winged Gull

Saemundssonia lari subsp.
Alaska, St. George Island

Alcidae

Cepphus columba — Pigeon Guillemot

Saemundssonia procax (Kellogg and Chapman, 1899)
Alaska, St. Paul Island

Brachyrampus marmoratum — Marbled Murrelet

Saemundssonia sp.
Bering Sea, at sea:
53°00' N x 168°55' W

Aethia pusilla — Least Auklet

Quadraceps aethereus (Giebel, 1874)
Alaska, St. Paul Island

Saemundssonia sp.
Alaska, St. Paul Island

PASSERIFORMES

Fringillidae

Melospiza melodia — Song Sparrow

Philopterus sp.
Alaska, Umnak Island

SOUTHEASTERN PACIFIC OCEAN

PROCELLARIIFORMES

Diomedeidae

Diomedea chrysostoma — Grey-headed Albatross
    Docophoroides simplex (Waterston, 1914)
        Pacific Ocean, off Chile.

Diomedea exulans — Wandering Albatross
    Docophoroides brevis (Dufour, 1835)
        Pacific Ocean, off Chile

    Harrisoniella hopkinsi Eichler, 1952
        Pacific Ocean, off Chile

PART II: MALLOPHAGA CHECKLIST

ISCHNOCERA

Philopteridae

Anaticola crassicornis dafilensis Carriker, 1956
    Host: Anas acuta

Anaticola crassicornis hopkinsi Eichler, 1954
    Anas clypeata

Anatoecus dentatus subsp.
    Anas acuta

Anatoecus sp.
    Anas crecca carolinensis
    Anas acuta
    Anas querquedula
    Aythya fuligula

Carduiceps cingulatus (Denny, 1842) (?)
    Limnodromus scolopaceus

Carduiceps meinertzhageni Timmermann, 1954
    Erolia ptilocnemis

Carduiceps scalaris (Piaget, 1880)
    Philomachus pugnax

Carduiceps zonarius (Nitzsch, 1866)
    Crocethia alba
    Erolia acuminata
    Ereunetes mauri
    Erolia melanotos

Docophoroides brevis (Dufour, 1835)
Diomedea exulans

Docophoroides pacificus ferrisi Harrison, 1937
Diomedea nigripes

Docophoroides pacificus subsp.
Diomedea immutabilis

Docophoroides simplex (Waterston, 1914)
Diomedea chrysostoma

Episbates pederiformis (Dufour, 1835)
Diomedea nigripes

Halipeurus bulweriae Timmermann, 1960
Bulweria bulwerii

Halipeurus diversus (Kellogg, 1896)
Puffinus griseus
Puffinus tenuirostris
Puffinus puffinus newelli

Halipeurus heraldicus Timmermann, 1960
Pterodroma alba

Halipeurus kermadecenae (Johnston and Harrison, 1912)
Pterodroma externa
Pterodroma neglecta

Halipeurus leucophryna Timmermann, 1960
Pterodroma cooki

Halipeurus marquesanus (Ferris, 1932)
Pterodroma rostrata

Halipeurus mirabilis Thompson, 1940
Puffinus pacificus

Halipeurus nesofregettae Timmermann, 1961
Nesofregetta albigularis

Halipeurus noctivagus (Timmermann, 1960)
Pterodroma phaeopygia

Halipeurus pelagicus (Denny, 1842)
Pterodroma hypoleuca
Pterodroma cooki
Oceanodroma castro

Halipeurus spadix Timmermann, 1961
    Puffinus nativitatus
    Puffinus lherminieri

Halipeurus theresae Timmermann, 1969
    Pterodroma hypoleuca

Harrisoniella densa (Kellogg, 1896)
    Diomedea immutabilis

Harrisoniella hopkinsi Eichler, 1952
    Diomedea exulans

Lunaceps holophaeus cabanisi Timmermann, 1954
    Ereunetes mauri

Lunaceps holophaeus holophaeus (Burmeister, 1838)
    Philomachus pugnax

Lunaceps numenii hopkinsi Timmermann, 1954
    Numenius tahitiensis

Lunaceps numenii phaeopi (Denny, 1842)
    Numenius phaeopus

Lunaceps sp.
    Erolia acuminata
    Erolia ptilocnemis

Naubates damma Timmermann, 1961
    Pterodroma externa

Naubates harrisoni Bedford, 1930
    Puffinus carneipes
    Puffinus harrisoni
    Puffinus nativitatus

Naubates pterodromi Bedford, 1930
    Pterodroma phaeopygia

Paraclisis confidens (Kellogg, 1899)
    Diomedea nigripes

Paraclisis giganticola (Kellogg, 1896)
    Diomedea immutabilis

Pectinopygus annulatus (Piaget, 1880)
    Sula dactylatra

Pectinopygus gracilicornis (Piaget, 1880)
    Fregata minor

Pectinopygus sulae (Rudow, 1869)
    Sula dactylatra
    Sula sula
    Sula leucogaster

Pectinopygus sp.
    Fregata ariel

Perineus nigrolimbatus (Giebel, 1874)
    Fulmarus glacialis

Perineus tenuipenalis Keler, 1958
    Diomedea immutabilis

Philopterus sp.
    Melospiza melodia

Quadraceps aethereus (Giebel, 1874)
    Aethia pusilla

Quadraceps birostris (Giebel, 1874)
    Sterna fuscata

Quadraceps charadrii hospes (Nitzsch, 1866)
    Squatarola squatarola

Quadraceps charadrii orarius (Kellogg, 1896)
    Pluvialis dominica

Quadraceps falcigerus (Peters, 1931)
    Totanus flavipes

Quadraceps hopkinsi Timmermann, 1952
    Anous tenuirostris

Quadraceps impar Hopkins and Timmermann, 1954
    Heteroscelus incanum

Quadraceps normifer parvopallidus (Eichler, 1951)
    Stercorarius longicaudis

Quadraceps obscurus (Burmeister, 1838)
    Tringa glareola

Quadraceps separatus (Kellogg and Kuwana, 1902)
    Anous stolidus

Quadraceps strepsilaris (Denny, 1842)
Arenaria interpres

Quadraceps sp.
Sterna lunata
Procelsterna cerulea

Saemundssonia albemarlensis (Kellogg and Kuwana, 1902)
Sterna fuscata

Saemundssonia conica conica (Denny, 1842)
Pluvialis dominica

Saemundssonia euryrhyncha (Giebel, 1874)
Stercorarius pomarinus

Saemundssonia hexagona (Giebel, 1874)
Phaethon rubricauda

Saemundssonia lari atricilla Carriker, 1956
Larus atricilla

Saemundssonia lari subsp.
Larus glaucescens

Saemundssonia limosae (Denny, 1842)
Limosa lapponica

Saemundssonia labaticeps remota Timmermann, 1951
Anous stolidus

Saemundssonia platygaster subsp.
Erolia acuminata

Saemundssonia procax (Kellogg and Chapman, 1899)
Cepphus columba

Saemundssonia puellula Timmermann, 1965
Puffinus pacificus

Saemundssonia scolopacisphaeopodis (Schrank, 1803)
Numenius tahitiensis
Numenius phaeopus

Saemundssonia snyderi (Kellogg and Paine, 1910)
Sterna lunata

Saemundssonia tringae (O. Fabricius, 1780)
Erolia acuminata
Ereunetes mauri
Erolia ptilocnemis

Saemundssonia uppaluensis (Rudow, 1870)
    Phaethon lepturus

Saemundssonia sp.
    Nesofregetta albigularis
    Thalasseus bergii
    Gygis alba
    Brachyramphus marmoratum
    Aethia pusilla

Trabeculus aviator (Evans, 1912)
    Puffinus puffinus newelli

Trabeculus fuscoclypeatus (Johnston and Harrison, 1912)
    Pterodroma neglecta

Trabeculus hexakon (Waterston, 1914)
    Pterodroma externa
    Pterodroma hypoleuca
    Pterodroma alba
    Pterodroma cooki
    Puffinus pacificus
    Puffinus griseus
    Puffinus tenuirostris
    Puffinus nativitatus

AMBLYCERA

Menoponidae

Actornithophilus bicolor (Piaget, 1880)
    Arenaria interpres

Actornithophilus ceruleus (Timmermann, 1954) (?)
    Anous tenuirostris

Actornithophilus incisus (Piaget, 1880)
    Anous stolidus
    Anous tenuirostris

Actornithophilus kilauensis (Kellogg and Chapman, 1902)
    Heteroscelus incanum

Actornithophilus limosae (Kellogg, 1908)
    Limosa lapponica

Actornithophilus ocellatus (Rudow, 1869)
    Numenius phaeopus

Actornithophilus ochraceus (Nitzsch, 1818)
    Pluvialis dominica

<u>Actornithophilus pediculoides</u> (Mjoberg, 1910)
    <u>Arenaria interpres</u>

<u>Actornithophilus piceus piceus</u> (Denny, 1842)
    <u>Sterna lunata</u>
    <u>Sterna fuscata</u>

<u>Actornithophilus umbrinus</u> (Burmeister, 1838)
    <u>Crocethia alba</u>
    <u>Erolia melanotos</u>

<u>Actornithophilus</u> sp.
    <u>Anous stolidus</u>
    <u>Gygis alba</u>

<u>Ancistrona vagelli</u> (J. C. Frabricius, 1787)
    <u>Pterodroma externa</u>
    <u>Pterodroma rostrata</u>
    <u>Pterodroma neglecta</u>
    <u>Puffinus pacificus</u>

<u>Austromenopon atrofulvum</u> (Piaget, 1880)
    <u>Sterna sumatrana</u>
    <u>Sterna lunata</u>
    <u>Sterna fuscata</u>

<u>Austromenopon miloni</u> (Seguy, 1949)
    <u>Phaethon lepturus</u>

<u>Austromenopon phaeopodis</u> (Schrank, 1802)
    <u>Numenius tahitiensis</u>
    <u>Numenius phaeopus</u>

<u>Austromenopon squatarolae</u> Timmermann, 1954
    <u>Squatarola squatarola</u>

<u>Austromenopon transversum</u> (Denny, 1842)
    <u>Larus atricilla</u>

<u>Austromenopon</u> sp.
    <u>Phaethon rubricauda</u>
    <u>Arenaria interpres</u>
    <u>Procelsterna cerulea</u>
    <u>Anous stolidus</u>
    <u>Anous tenuirostris</u>

<u>Colpocephalum angulaticeps</u> Piaget, 1880
    <u>Fregata minor</u>

Eidmanniella albescens (Piaget, 1880)
    Sula dactylatra
    Sula sula
    Sula leucogaster

Fregatiella aurifasciata (Kellogg, 1899)
    Fregata minor

Holomenopon clypeilargum Eichler, 1943 (?)
    Anas acuta

Longimenopon sp.
    Pterodroma cooki

Procellariphaga affinis (Piaget, 1890)
    Diomedea nigripes
    Diomedea immutabilis

Procellariphaga enigki (Timmermann, 1963)
    Pterodroma hypoleuca

Procellariphaga paulula (Kellogg and Chapman, 1899)
    Puffinus pacificus
    Puffinus griseus

Procellariphaga sp.
    Pterodroma externa
    Pterodroma alba

Trinoton querquedulae (Linnaeus, 1758)
    Anas crecca carolinensis
    Anas penelope
    Anas acuta
    Anas querquedula
    Aythya fuligula

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RAINFALL ON INDIAN OCEAN CORAL ISLANDS

by D. R. Stoddart

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RAINFALL ON INDIAN OCEAN CORAL ISLANDS

by D. R. Stoddart[1/]

1. INTRODUCTION

The existence of steep rainfall gradients in the tropical Pacific is well documented, and many workers have drawn attention to the effects of rainfall variations on island ecologies, particularly in the Gilbert and Marshall Islands. Rainfall gradients also exist in the Indian Ocean, but fewer records are available for islands in this area, and the spatial patterns of rainfall distribution and variability are still only approximately known.

As part of a programme of work on coral islands and reefs in the Indian Ocean, particularly in the western and central sectors, an attempt has been made to assemble rainfall data from as many coral island stations as possible in order to demonstrate the extent of spatial and temporal variability. This paper summarizes these records, and the data are used as the basis of a series of maps of the Indian Ocean showing the distribution of annual, seasonal and monthly rainfalls. Because the paper is concerned only with the establishment of rainfall patterns, no attempt is made to relate these patterns to climatological causal factors.

Studies of rainfall over the oceans and on oceanic islands are subject to peculiar difficulties. Stations are generally few in number and far apart, and, in the Indian Ocean, are markedly clustered in the western sector. The longest, most continuous, and most reliable records are usually those from high islands, such as the Mascarenes and the Comoros, where, however, orographic and other local effects lead to rainfalls unrepresentative of the surrounding ocean area. An extreme example is given by Réunion, in the Mascarenes, where relief effects

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combined with a tropical cyclonic disturbance to give a world record rainfall intensity of 187 cm over 24 hr in 1952 (Paulhus 1965). In contrast, coral island records are, with some exceptions, brief, often incomplete, and in some cases maintained by untrained and unsupervised observers.

Records are presented in this paper for 21 Indian Ocean coral island stations. These are listed, with period of record, mean annual rainfall over this period, and variability, in Table 1. The standard deviation of annual rainfalls is calculated for those stations with a period of record greater than ten years, and variability is given by 100 $\sigma/\bar{X}$. The data used are derived from a variety of sources. Records for Cargados Carajos, Agalega, Salomon, Peros Banhos and Diego Garcia are published by the Mauritius Department of Meteorology in the monthly Results of Magnetical and Meteorological Observations from the Royal Alfred Observatory (up to 1950) and in the monthly Meteorological Observations and Climatological Summaries (1951-). Records for Amini Divi, Androth and Agathi, in the Laccadive Islands, while not included in Monthly rainfall of India, have been made available by the Meteorological Department, Government of India, at Poona. The Meteorological Department, Bracknell, England, has provided published and unpublished records for Christmas Island, Cocos Keeling, Minicoy and Tromelin. Many shorter records have been abstracted during visits to Indian Ocean islands, mostly from records in the Department of Meteorology, Mahé, Seychelles (Aldabra, Alphonse, Bird, Darros, Denis and Poivre). Figures for Addu Atoll were obtained from the Royal Air Force, Gan, and for Assumption from the island Manager. Figures for Malé have been published by Wells (1948).

2. SPATIAL DISTRIBUTION OF ANNUAL RAINFALL

The first serious attempt to map the distribution of rainfall over the oceans was that of Supan (1898), but because of lack of data most of the Indian Ocean was left blank in his map. Indian Ocean data were first assembled by Schott (1933, 1935, pl. 19) and Meinardus (1934), and their maps are given in Figures 1A and 1B. These both show an equatorial belt of high rainfall (greater than 2000 mm per annum) extending from east to west across the ocean almost to the Seychelles, with totals greater than 3000 mm in the easternmost area. Broadly similar maps have been published by The Times Atlas of the World (Bartholomew, editor, 1958: Figure 1C) and by the Russian Norskoi Atlas (Drozdov 1953) and the Fiziko-Geograficheskiy Atlas Mira (Kuznetsova and Sharova 1964: Figure 1D). These later maps show the area enclosed by the 2000 mm isohyet to be rather more extensive, including the Seychelles and Amirantes, and in the case of the Russian map the Aldabra group as well. These maps are based mainly on records from high island stations (Rodriguez, Réunion, Mauritius, Mahé, Socotra, and stations in the Andamans and Nicobars). Only four coral island stations are used, all with long periods of record: these are Minikoi, Diego Garcia,

Cocos-Keeling and Christmas Island (the latter an elevated reef island rising to a maximum elevation of 360 m). Records from the high islands certainly exaggerate oceanic rainfalls, and arbitrary reduction factors are used when drawing isohyets for the open ocean. In addition, large areas of the Indian Ocean lack any island records at all, and isohyets are interpolated based on general considerations of atmospheric circulation and pressure distribution. These problems are discussed by Wust (1950) and Jacobs (1968).

Figure 2 plots mean annual rainfall totals for all the coral islands for which data are available. As noted in Table 1, these records vary widely in length and continuity. A distinction is therefore made in Figure 2 between stations with more and those with less than 10 years of record. Because of the variability of coral island rainfalls short period records are generally of little value in deriving mean values for isohyet plotting: compare, for example, the length of record and mean annual rainfall for three stations in the Amirantes (Alphonse, 14 yr, 1930 mm; Darros 12 yr, 1497 mm; Poivre, 2 yr, 2045 mm). Figure 2 is thus based primarily on the values for stations with records longer than 10 years. Mean values for some high island stations in the Seychelles and the Mascarenes are also shown, but these were not used in drawing the isohyets.

Coral islands give a better indication of open-ocean rainfall than high islands, because their small size and lack of height lead to minimal topographic effects. In a detailed study of rainfall incidence at Eniwetok Atoll, Marshall Islands, for example, Lavoie (1963) concluded that the atoll itself has a negligible effect on rainfall amounts and incidence. It is reasonable to conclude, therefore, that the isohyets drawn from coral island records in Figure 2 define a map of the distribution of rainfall over the ocean.

The general pattern shown in Figure 2 resembles those in Figure 1, with two important differences: (a) Figure 2 shows the existence in the central Indian Ocean of rainfalls in excess of 3000 mm, rather than the 2000 mm of the earlier maps, with maxima of more than 3700 mm in the northern Chagos atolls of Peros Banhos and Salomon; and (b) Figure 2 also shows the existence in the southwest Indian Ocean, north of Madagascar, of an area with less than 1000 mm per annum (about 800 mm on Aldabra and Assumption). Rainfall in the Amirantes is also lower in Figure 2 than in Figure 1. Gradients in rainfall over the Indian Ocean are thus considerably steeper than suggested by previously published maps: the most striking gradient is that from the Chagos Archipelago northwards to the Laccadives along an almost continuous chain of atolls, though lower annual totals are found along the gradients from the Chagos across the western Indian Ocean to the Aldabra group.

It is interesting to compare the mean annual rainfalls of Indian with Pacific Ocean atolls. Table 3 lists some Pacific atolls which may be compared with coral islands in the Indian Ocean in terms of mean annual rainfall.

3. SEASONAL RAINFALL DISTRIBUTION

Maps of the seasonal distribution of rainfall over the oceans have been prepared by Möller (1951) and Jacobs (1968). Figure 3 shows the distribution of mean rainfall for the three-monthly periods December-February, March-May, June-August, and September-November according to Möller. These show a seasonal maximum in the central Indian Ocean (Chagos Archipelago) in December-February, and in the Maldives during the southwest monsoon of June-November. The influence of the monsoonal system in the northern Indian Ocean leads to a change in direction of the isohyets from east-west to north-south during the northern summer. Möller's maps are based mainly on high island records.

Plotting coral island data for the same seasons gives the distributions shown in Figure 4. The patterns are similar to Möller's but the magnitudes are considerably different. In each season Möller underestimates the amount of rainfall in the central area, and also the westward extent of the high rainfall belt. Discrepancies between Möller's values and those in Figure 4 are greatest in the Chagos archipelago and least in the Aldabra group.

4. MONTHLY RAINFALL DISTRIBUTION

Maps of the spatial distribution of mean monthly rainfall have been published by Albrecht (1951), mainly from high island data. Figures 5 and 6 show isohyets for each month of the year for coral island stations. All stations were plotted, but the isohyets are mainly based on stations with records longer than 10 years. Mean monthly figures for all the reef island stations are given in Table 2.

The monthly maps clearly show the concentration of rainfall in the central equatorial belt during January, February, March and April; the increasing rainfall associated with the Indian summer monsoon extending northwards through the Maldives during May; the reversal of the latitudinal rainfall gradient during the monsoon proper, in June, July and August, with highest rainfall in the Laccadives, decreasing southwards; and finally the retreat of the monsoon and re-establishment of the equatorial maximum in September, October, November and December. In the southwest Indian Ocean, highest monthly rainfalls occur in November and December (about 50 mm), January (100 mm), February (150 mm), March (100 mm) and April 150 mm). There is a similar monthly pattern in the eastern Indian Ocean, at Cocos-Keeling and Christmas Island, though totals are higher.

5. INDIVIDUAL STATIONS

Data for individual stations with longer periods of record are presented in the form of scatter diagrams, showing actual rainfall for each month of record and the arithmetic mean over the period of record, in Figures 7-11. Mean annual and mean monthly totals for these stations are given in Tables 1 and 2. The actual monthly figures for these stations and for those with only a short period of record are available on request. The stations are grouped geographically, and brief observations may be made on each group.

In the Maldives and Laccadives, good records are available for Addu, Minicoy and Amini Divi (Figure 7), spanning a north-south distance of 1300 km. At Addu the rainfall is dominated by the migration north and south of equatorial shear zones and no monsoonal influence is apparent (Stoddart, editor, 1966). At Minicoy and Amini Divi, however, annual totals are higher and there is a pronounced seasonal maximum in May-December and minimum in January-April. The monsoon is apparent earlier at Minicoy than at Amini Divi. As annual totals increase, so does variability, from 13 to 23%.

In the Chagos to the south (Figure 8), with the highest annual totals of all Indian Ocean atolls, rainfall distribution is approximately bimodal, with peaks in January-February and October. Variability is high, especially on Salomon (23%) and Peros Banhos (30%), but these are the only Indian Ocean atolls where completely dry months do not occur. Very high monthly totals are frequently recorded, with a maximum of 1037 mm in June 1952--the second highest monthly total recorded on an Indian Ocean coral island (the highest being 2208 mm in January 1965 at Cocos-Keeling Atoll).

Figure 9 shows trade-wind stations in the central Indian Ocean, and Figure 10 similar stations in the western Indian Ocean. All show an alternation between a dry period during the Southeast Trades, roughly May-November, and a rainy season during the calms of northwesterlies of December-April. Variability is greatest during the wettest months and least during the Trades, when a proportion of months, particularly in the western Indian Ocean, are completely dry.

Rainfall records are available for only two eastern Indian Ocean coral islands, Cocos-Keeling and Christmas Islands. Both show a maximum during the early part of the year and a pronounced minimum during September and October. Variability is higher at Christmas Island, where the record is however much longer.

No analysis is undertaken in the present paper of patterns in the temporal variation of rainfall. However, it can be stated that there is good correlation in the occurrence of wet and dry years in particular geographic areas. Thus the three Chagos atolls of Diego Garcia, Peros Banhos and Salomon, together with Addu Atoll in the

Maldives, show very similar temporal patterns; as do islands in the Seychelles area (for example Darros and Denis) and, to a lesser extent, Minicoy and Amini Divi.

ACKNOWLEDGEMENTS

I thank the Directors, Meteorological Department, Bracknell, England; Department of Meteorology, Mauritius; and Meteorological Department, Government of India, New Delhi and Poona, for providing most of the data on which this paper is based. I also thank the staff of the Meteorological Department, Mahé, Seychelles, and of the Meteorological Station, Royal Air Force, Gan, for permission to abstract their records, and the Manager, Assumption Island, for his rainfall data. Aldabra records up to 1959 are from the Meteorological Department, Mahé, and since 1967 from the records of the Royal Society Expedition to Aldabra. I thank Mr. M. Young, Mr. C. Lewis and Mr. R. Coe for their work on the illustrations.

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TABLE 1.
INDIAN OCEAN RAINFALL STATIONS, WITH DETAILS OF LENGTH OF RECORD, MEAN ANNUAL RAINFALL, AND VARIABILITY

Station	Latitude	Longitude	Number of complete years of record	Period of record	Mean annual rainfall mm	σ mm	$100\sigma/\overline{X}$
Addu	0.38 S	73.10 E	9	1957-1967	2382.5	316.1	13.26
Agalega	10.22 S	56.37 E	20	1947-1966	1688.4	310.2	18.37
Agathi	10.59 N	72.14 E	3	1965-1968	1225.1	-	-
Aldabra	9.26 S	46.25 E	5	1949-1953, 1958-1959, 1967-1970	760.1	-	-
Alphonse	7.05 S	52.50 E	14	1949-1962	1350.0	256.1	18.97
Amini Divi	11.30 N	72.58 E	60	1901-1953, 1955-1963, 1965-1968	1515.9	348.6	23.23
Androth	10.51 N	73.41 E	1	1965-1968	2022.3	-	-
Assumption	9.45 S	46.30 E	2	1964-1967	867	-	-
Bird	3.41 S	55.06 E	2	1961-1962	1973.3	-	-
Cargados	16.27 S	59.36 E	20	1947-1966	973.6	272.0	27.93
Christmas	10.30 S	105.40 E	48	1901-1941, 1947-1952, 1965-1967	2037.8	578.5	23.38
Cocos-Keeling	12.00 S	96.50 E	15	1952-1968	2006.5	724.9	36.12
Darros	5.45 S	53.40 E	12	1950-1962	1496.7	393.8	26.31
Denis	3.47 S	55.39 E	12	1951-1962	1730.0	383.8	22.18
Diego Garcia	6.34 S	72.24 E	18	1937-1938, 1950-1966	2598.9	464.9	17.88
Male	4.00 N	73.28 E	4	c. 1941-1944	2055.9	-	-
Minicoy	8.29 N	73.01 E	65	1891-1895, 1897-1968	1628.1	242.3	14.88
Peros Banhos	5.18 S	72.00 E	14	1950-1966	3998.9	1184.7	29.62
Poivre	5.50 S	53.20 E	2	1961-1962	2045.2	-	-
Salomon	5.16 S	72.25 E	15	1949-1966	3750.7	860.3	22.93
Tromelin	15.51 S	54.25 E	11	1955-1968	1073.3	188.0	17.51

TABLE 2.
MEAN MONTHLY RAINFALLS OF INDIAN OCEAN CORAL ISLANDS (mm)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Addu	249.3	123.4	93.3	193.7	231.2	219.4	162.7	177.8	151.7	287.9	210.3	247.2
Agalega	252.4	195.9	158.1	156.3	146.9	91.4	99.0	76.1	80.6	118.4	106.2	207.5
Agathi	10.1	0	0.7	5.1	46.2	309.0	296.7	135.9	144.0	78.5	84.6	115.1
Aldabra	93.8	118.5	121.0	164.2	36.8	19.9	20.5	11.7	10.6	5.8	54.8	57.2
Alphonse	246.4	201.7	140.7	143.6	65.5	50.0	35.5	34.3	52.4	80.0	111.5	189.0
Amini Divi	16.8	2.6	3.4	23.8	142.1	374.7	314.3	204.0	149.0	146.0	83.2	38.8
Androth	21.1	0	19.7	29.0	76.7	325.2	415.5	260.6	159.9	128.6	118.2	201.7
Assumption	164	96	126	169	45	31	32	39	6	6	39	95
Bird	290.8	295.6	81.9	127.6	107.1	18.4	29.8	148.6	294.5	123.5	290.7	164.3
Cargados Carajos	167.1	158.0	176.0	11.36	56.9	47.7	56.3	47.1	21.3	24.0	29.2	76.4
Christmas	221.3	284.9	271.3	226.0	201.8	149.6	107.0	55.7	48.9	60.2	173.6	193.3
Cocos-Keeling	325.9	136.4	225.8	202.4	171.9	182.2	213.4	151.8	61.9	92.0	79.4	170.9
Darros	254.2	186.0	151.2	134.4	124.4	48.6	34.3	40.4	68.3	122.2	104.5	226.9
Denis	297.4	175.5	142.3	102.3	109.1	104.2	35.2	103.3	126.4	140.6	134.2	248.9
Diego Gracia	297.1	264.7	201.8	194.0	172.6	153.2	149.3	166.0	190.0	260.9	198.6	221.8
Malé	220.7	7.1	89.2	110.5	185.8	178.2	155.1	135.4	125.8	357.2	129.5	361.4
Minicoy	45.0	24.2	21.1	60.1	184.1	293.7	228.8	196.5	163.6	190.2	137.5	89.1
Peros Banhos	387.5	407.6	296.1	300.7	238.6	160.5	314.3	266.8	321.9	402.1	351.4	371.9
Poivre	397.6	245.2	147.8	189.7	52.4	95.2	43.1	57.5	222.8	189.4	172.8	231.1
Salomon	431.7	384.9	255.5	250.0	282.0	160.6	339.4	241.7	356.4	421.7	292.1	291.5
Tromelin	199.6	136.6	191.7	109.3	61.9	55.6	81.3	60.2	32.2	34.1	42.4	107.6

TABLE 3.

MEAN ANNUAL RAINFALLS OF INDIAN AND PACIFIC OCEAN ATOLLS (mm).
PACIFIC OCEAN DATA FROM WIENS (1962)

Indian Ocean		Pacific Ocean	
Peros Banhos	3999	Jaluit	3988
Salomon	3751	Palmyra	3810
		Funafuti	3378
		Washington	3099
		Majuro	3048
Diego Garcia	2599	Lamotrek	2641
Addu	2382	Manihiki	2413
		Palmerston	2108
Malé	2056	Fanning	2057
Poivre	2045	Nauru	2057
Christmas	2038		
Androth	2022		
Cocos-Keeling	2006	Niue	2007
Bird	1937	Ujelang	1956
Denis	1930	Ocean	1930
		Mopelia	1854
Agalega	1688		
Minicoy	1628	Tarawa	1626
Amini Divi	1516		
Darros	1497	Rangiroa	1473
		Christmas	1473
Alphonse	1350	Eniwetok	1346
Agathi	1225		
		Onotoa	1168
		Raroia	1168
Tromelin	1073		
Cargados Carajos	974		
Assumption	867	Hull	838
Aldabra	760	Malden	711
		Wake	610
		Canton	432

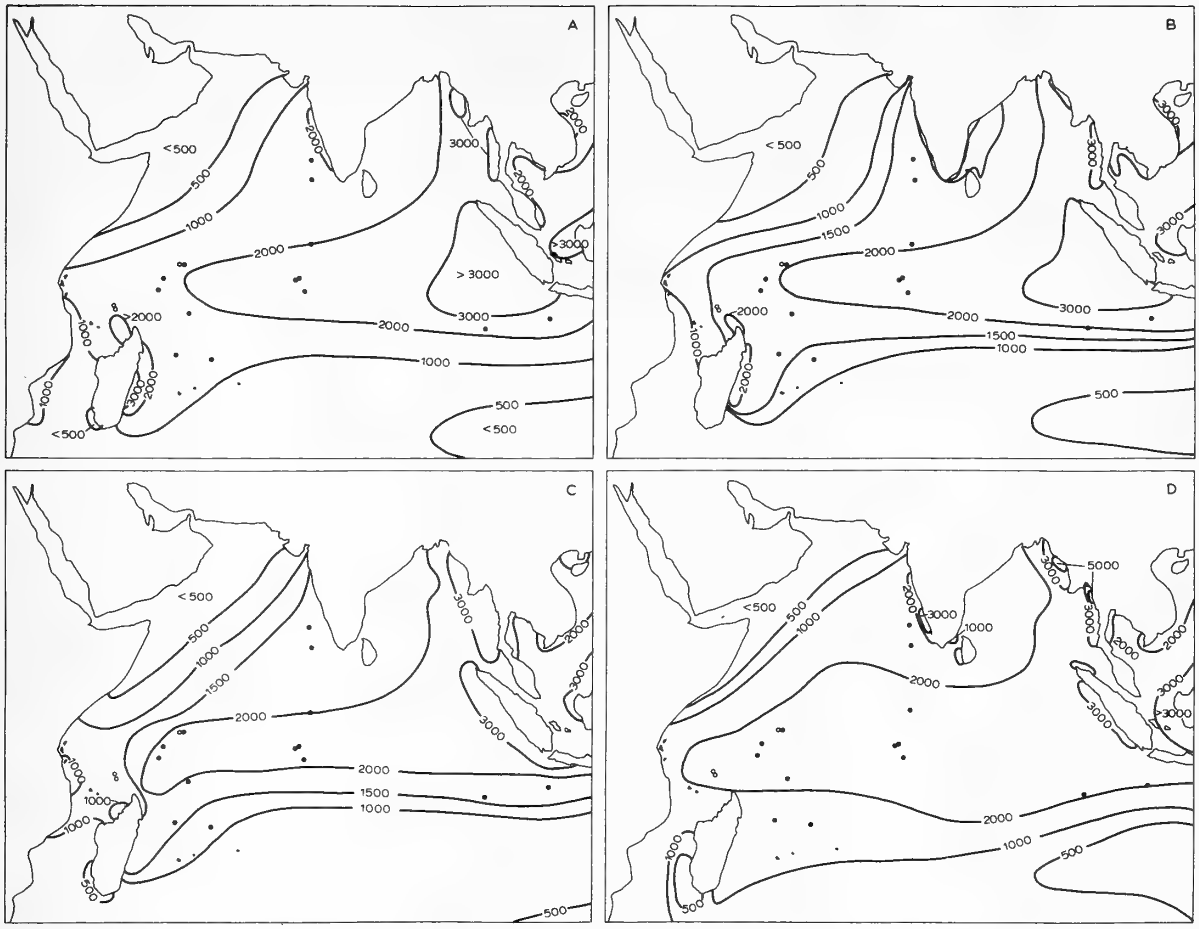

Fig. 1. Distribution of mean annual rainfall over the Indian Ocean (mm). A: Meinardus (1934). B: Schott (1933, 1935). C: Bartholomew (1958). D: Kuznetsova and Sharova (1964). The stations shown are those used in this paper and not those on which these authors based their maps.

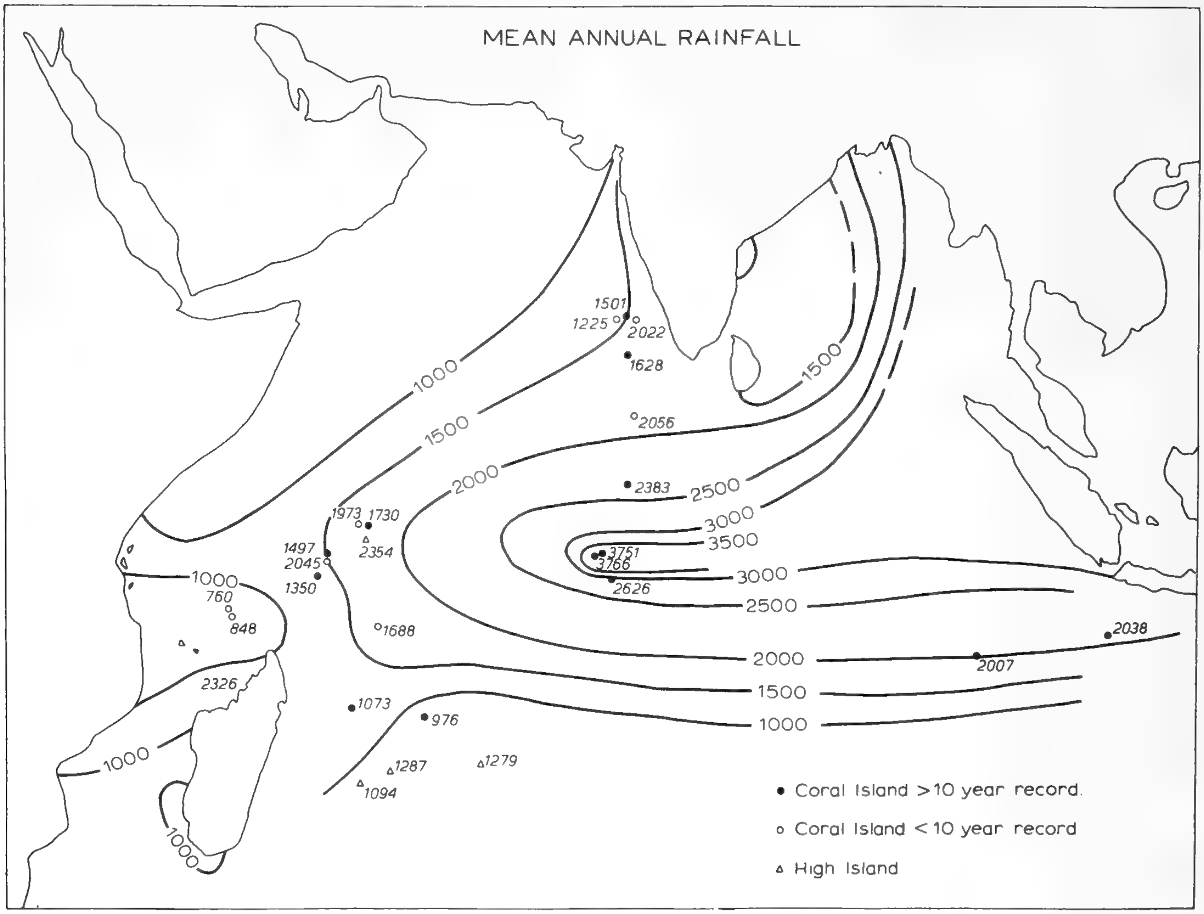

Fig. 2. Distribution of mean annual rainfall over the Indian Ocean (mm), with isohyets based on coral island stations with records longer than 10 years.

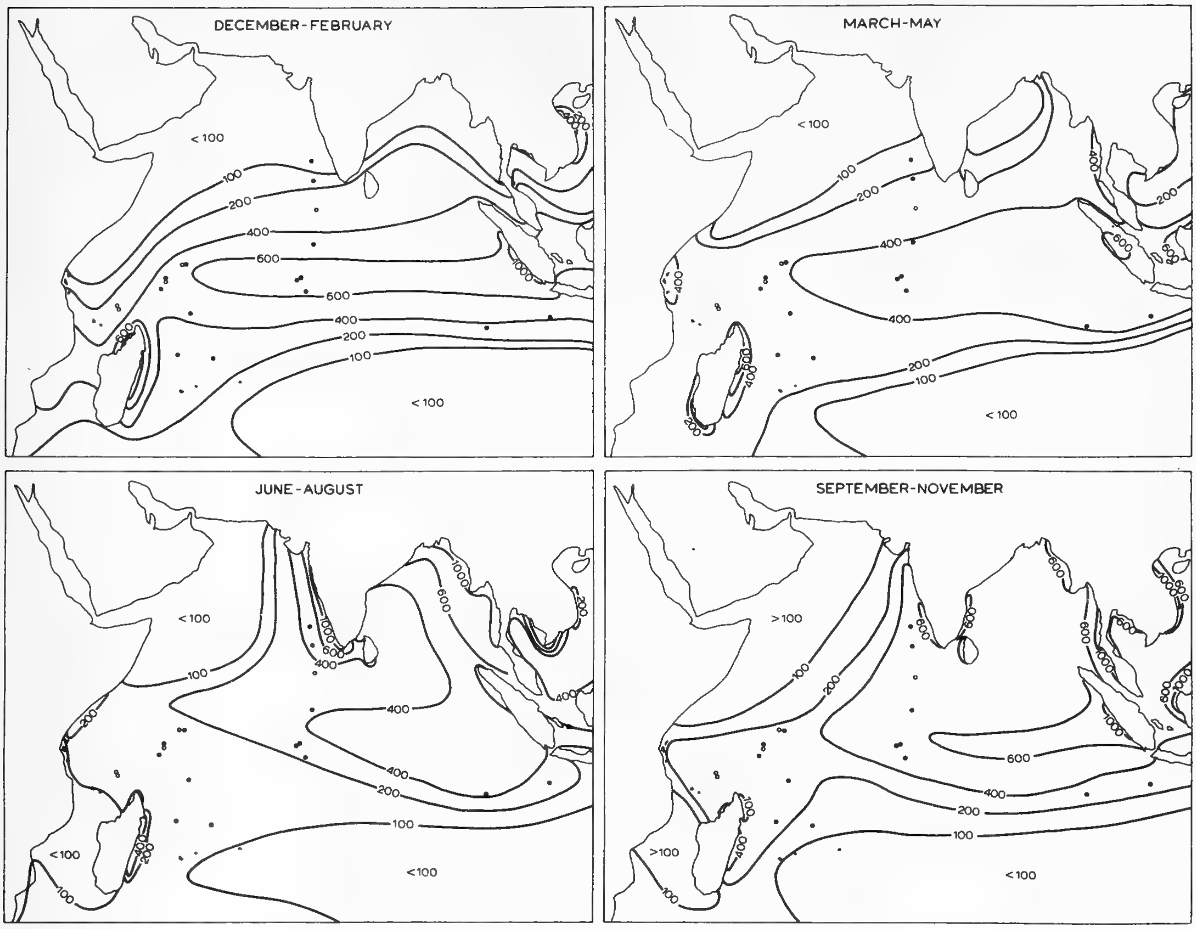

Fig. 3. Seasonal distribution of rainfall over the Indian Ocean (mm), after Möller (1951). The stations shown are those used in this paper and not those used by Möller.

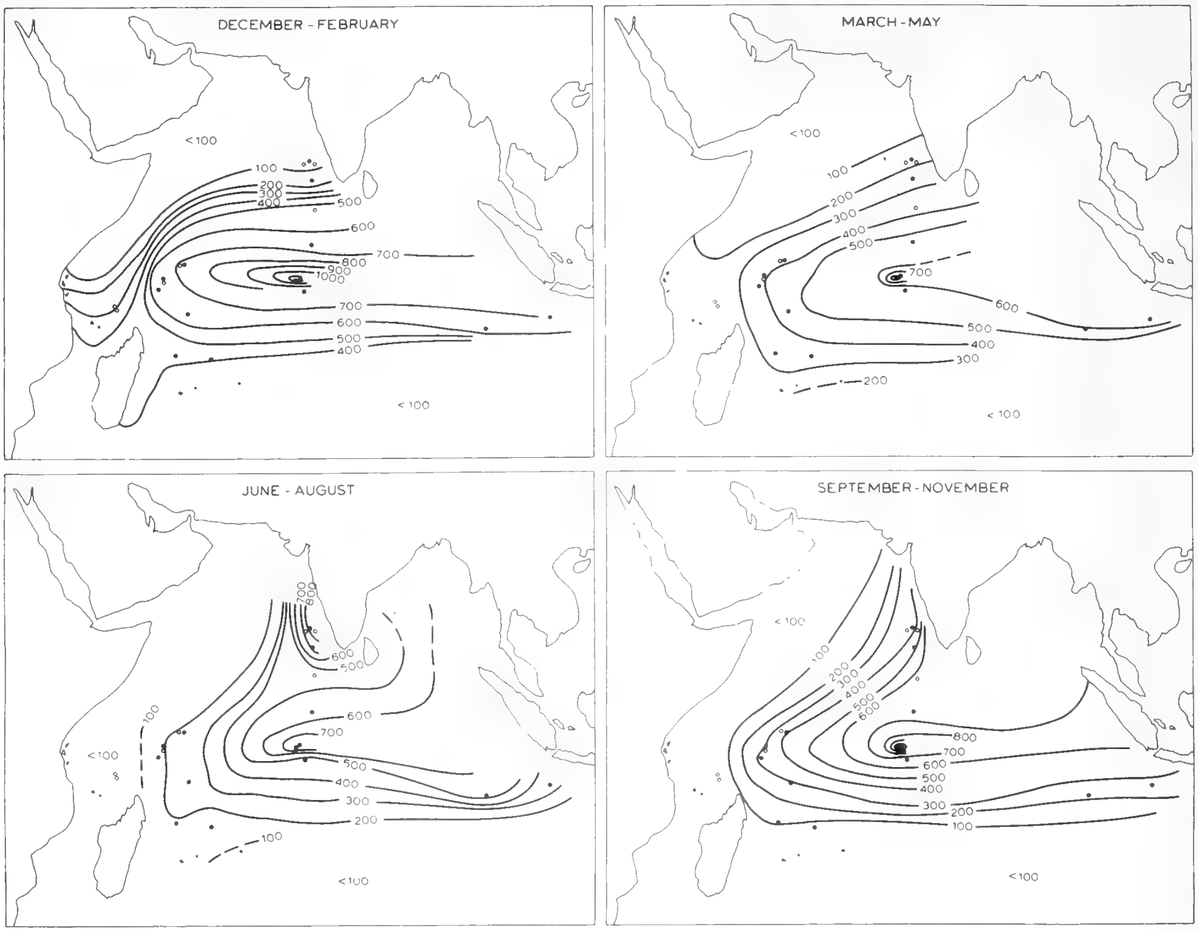

Fig. 4. Seasonal distribution of rainfall over the Indian Ocean (mm), based on coral island stations. Open circles: stations with records shorter than 10 years; dots, records longer than 10 years.

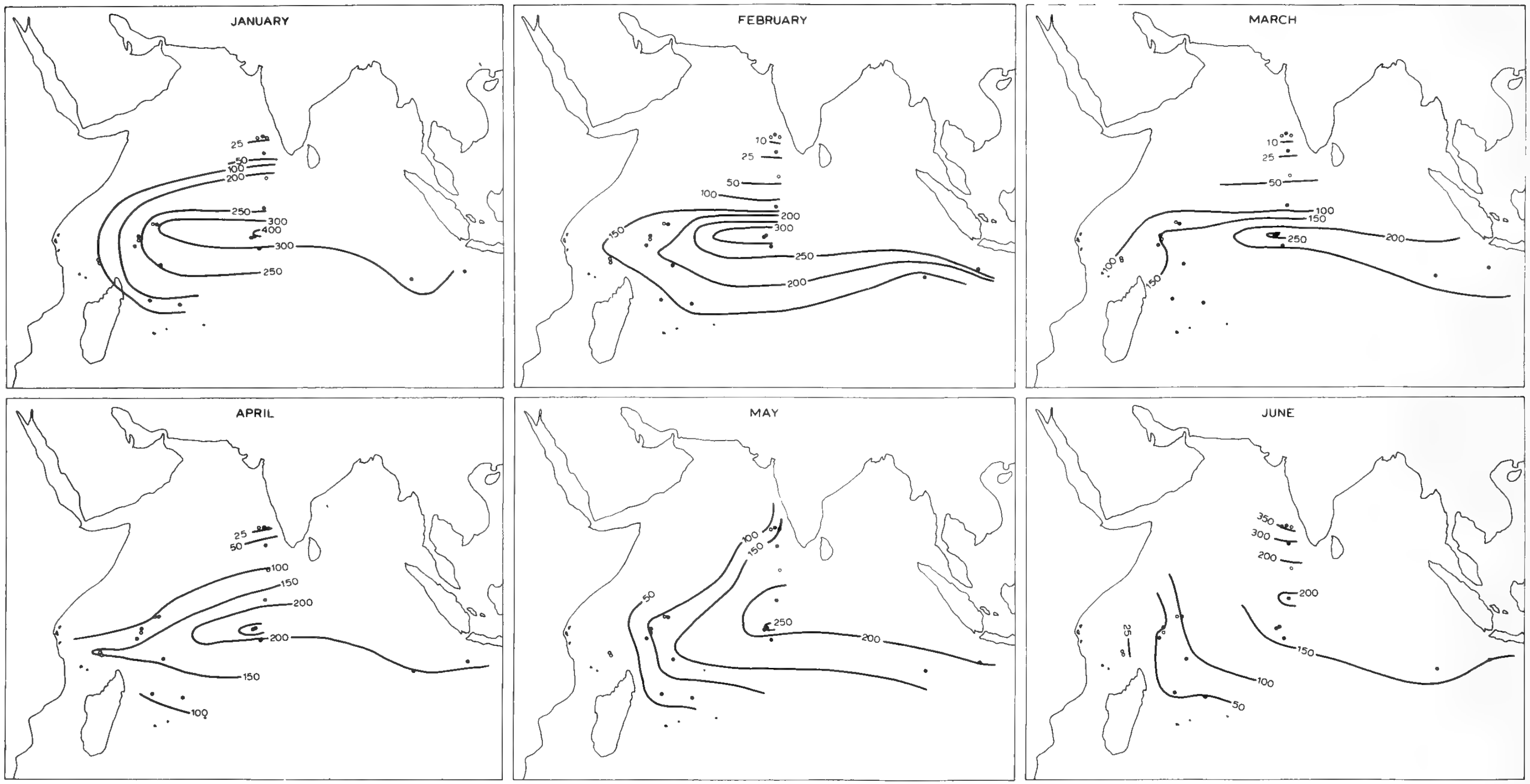

Fig. 5. Distribution of ~~mean~~ monthly rainfall over the Indian Ocean (mm), January-June, based on coral island data. Open circles: stations with records shorter than 10 years; dots, records longer than 10 years.

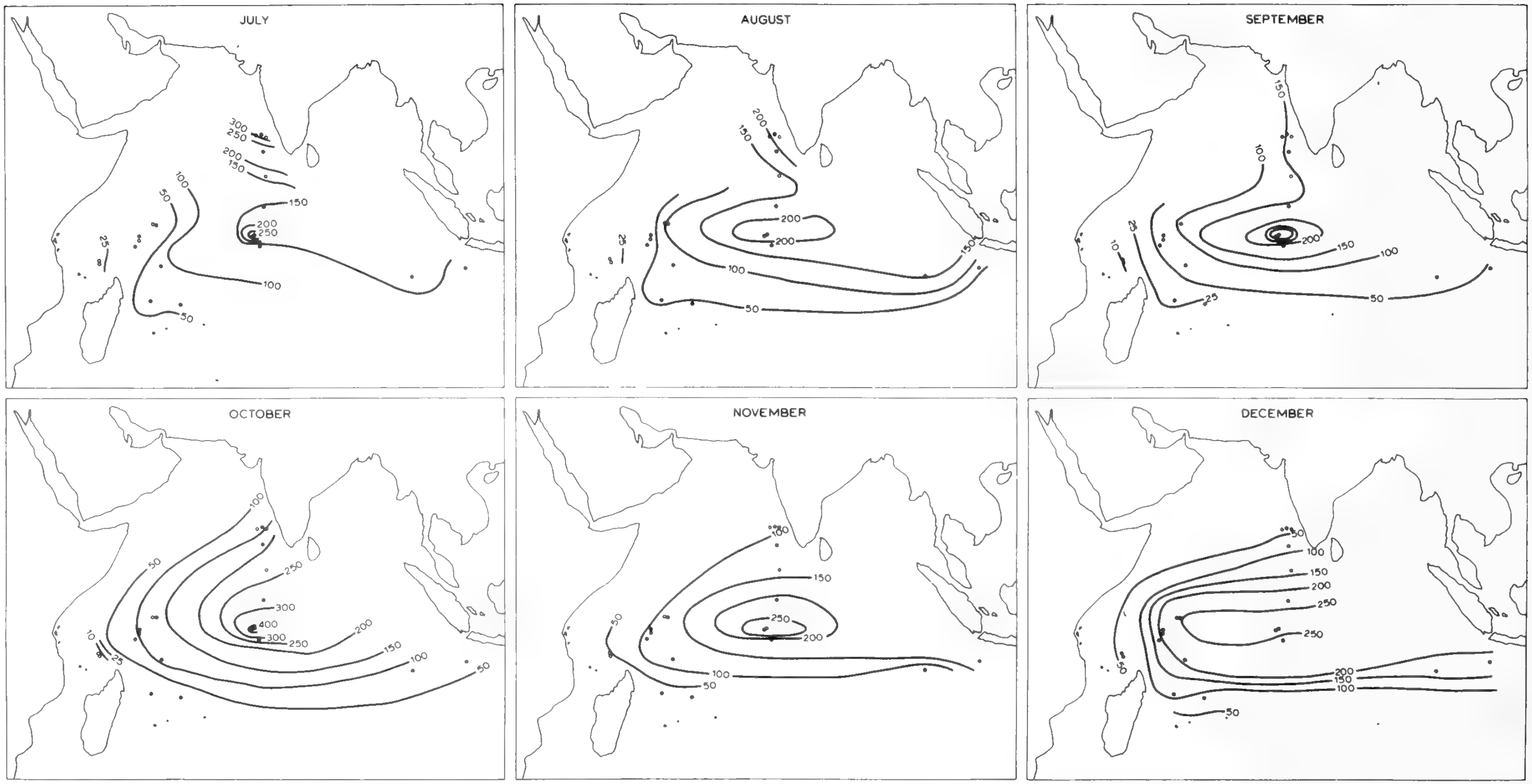

Fig. 6. Distribution of mean monthly rainfall over the Indian Ocean (mm), July-December. Conventions as for Figure 5.

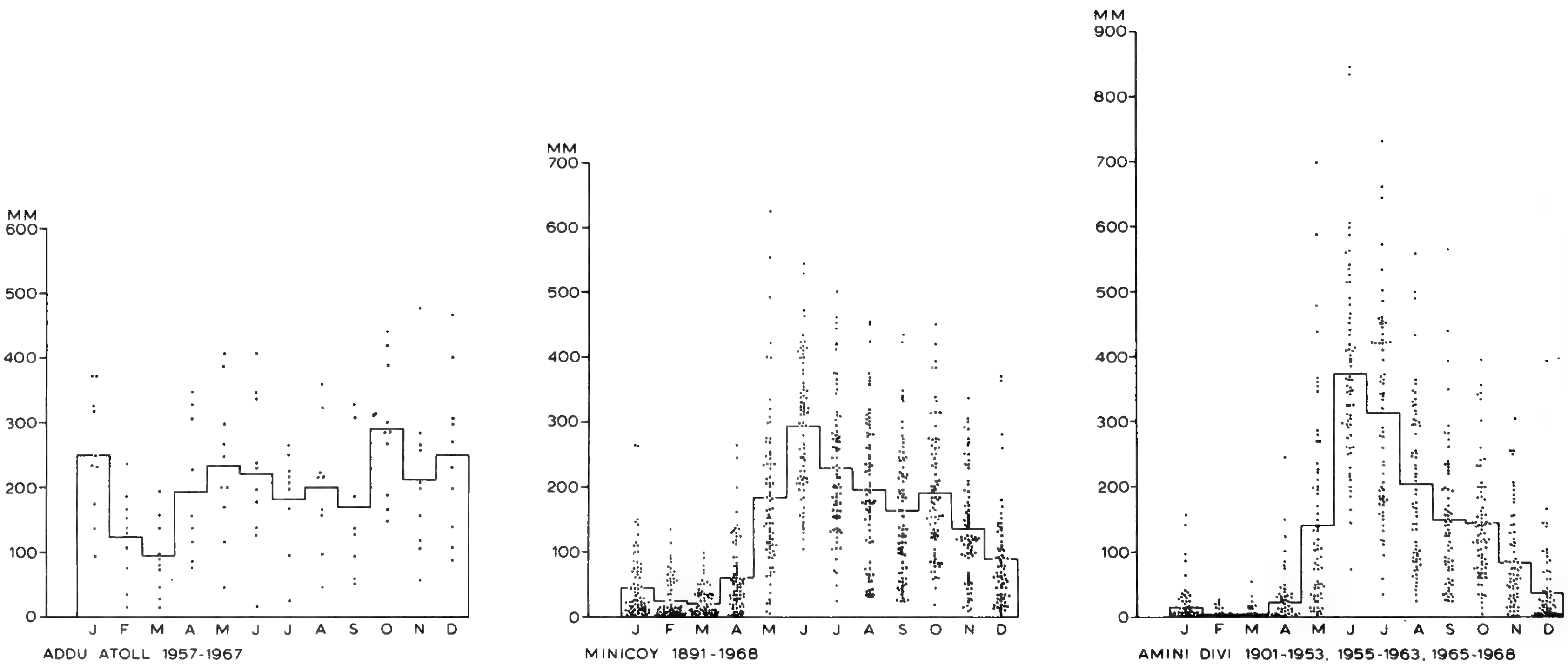

Fig. 7. Mean monthly rainfall and actual monthly totals over the period of record for Addu Atoll, Minicoy and Amini Divi.

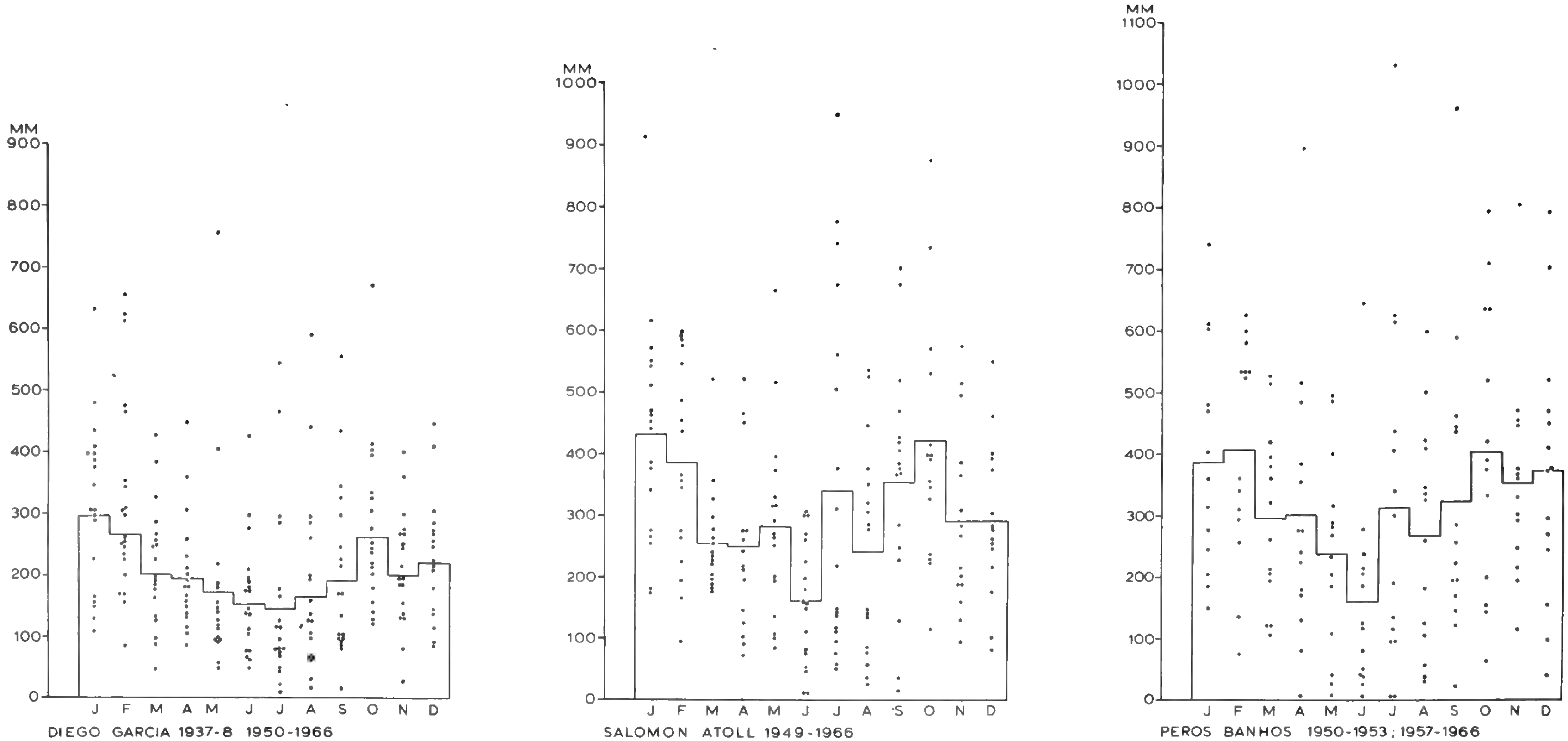

Fig. 8. Mean monthly rainfall and actual monthly totals over the period of record for Diego Gracia, Salomon and Peros Banhos Atolls, Chagos Archipelago.

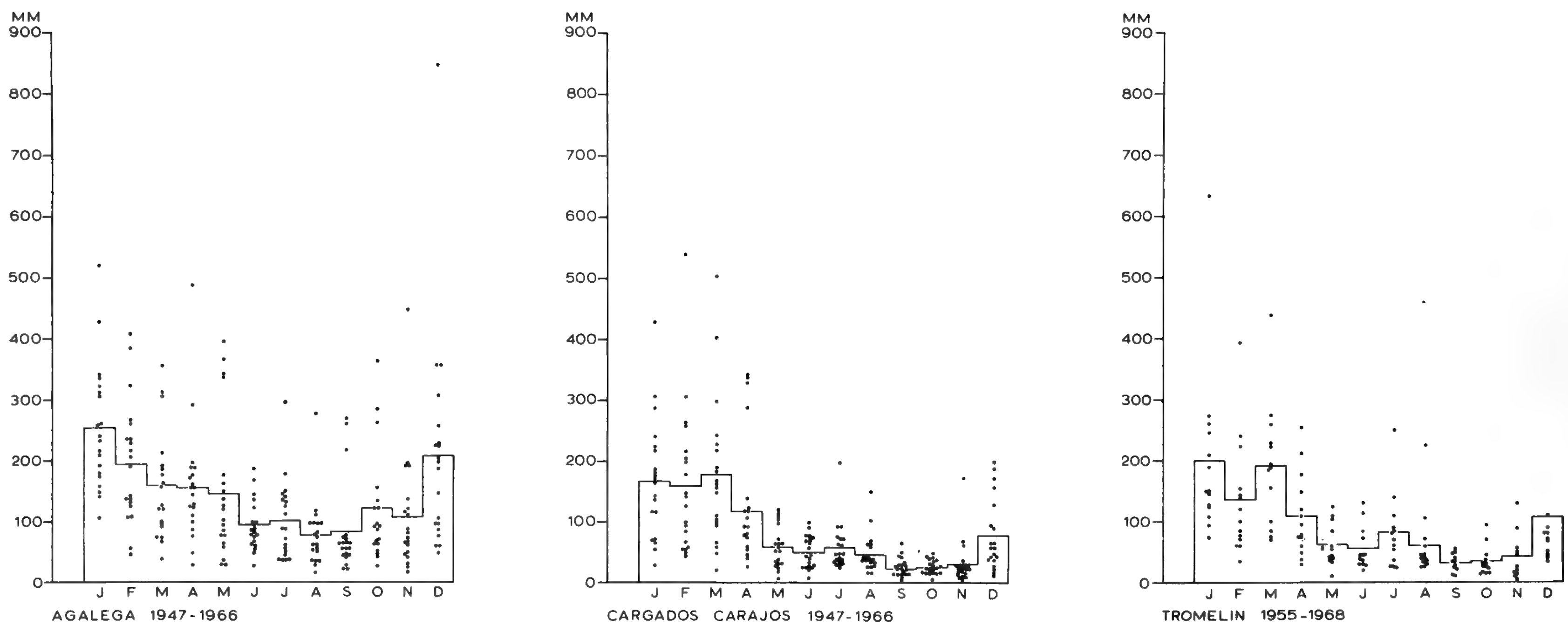

Fig. 9. Mean monthly rainfall and actual monthly totals over the period of record for Agalega, Cargados Carajos and Tromelin.

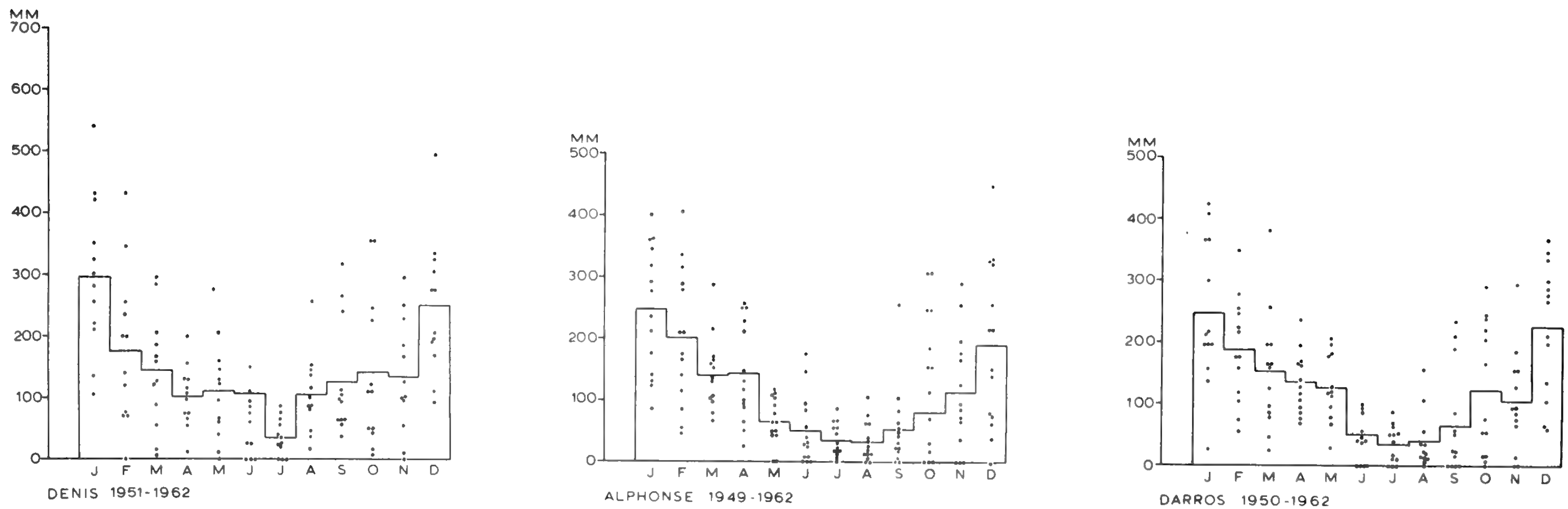

Fig. 10. Mean monthly rainfall and actual monthly totals over the period of record for Dennis, Alphonse and Darros.

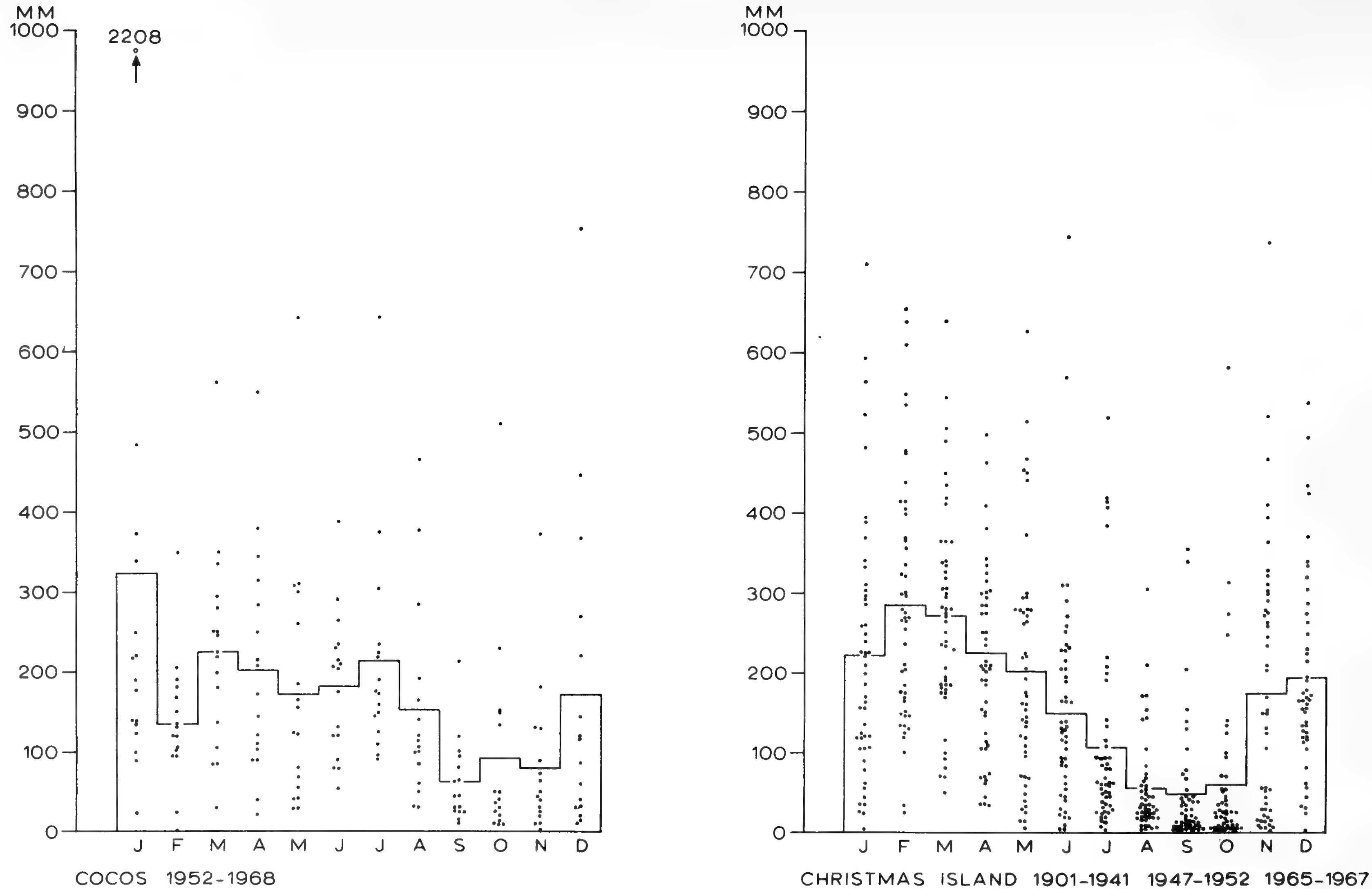

Fig. 11. Mean monthly rainfall and actual monthly totals over the period of record for Cocos-Keeling and Christmas Islands.

ATOLL RESEARCH BULLETIN

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ISLAND NEWS AND COMMENT

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ISLAND NEWS AND COMMENT

Many papers recently submitted for publication in ARB have been in very sloppy condition and have given the editors a great deal of extra work. Some, though the contents were of interest and value, showed evidence of hasty preparation and low professional writing standards. We accepted most of these and tried to improve them so they would not be an embarrassment either to the authors or to the editors. Demands on our time are such that we cannot afford to continue to offer this service. Henceforth, manuscripts received in a condition that requires extensive editing will most likely be returned to the authors for revision.

Briefly, the editoral standards for manuscripts are as follows: They must be typed double-space on letter-size (approximately 8 1/2 x 11 inch--20.5 x 27.5 cm, the size of an ARB page) rather than legal or other outsize pages that will not fit in a letter-size filing drawer. The grammar must be reasonably good, the writing clear, and cross-references to the figures unambiguous. Figure captions must be clear and pertinent, and the figures should be listed. Above all, the bibliographic references should be in the form commonly used in the ARB--i.e. author, title, period, inclusive pages, comma, place of publication, comma, year, if a book; or author, title, journal abbreviation, period, series in Roman numerals, comma, volume in Arabic numerals, number in parentheses, colon, inclusive pages, comma, year. Anything added, not appearing in the item cited, should be enclosed in square brackets. Nothing should be underlined except Latin names. Carefully verify references by checking with the original publication so they will be correct to begin with.

We do not publish new taxa nor new combinations.

Articles on coral islands and reefs are given preference, but anything of ecological interest, in the broadest sense, on tropical islands is accepted if otherwise up to our standards.

NEWS

ALDABRA: A previous issue of Island News and Comment (ARB 126: 1969) gave an outline account of the progress of the Royal Society Expedition to Aldabra between August 1967 and March 1968 (Phases I-III). Since

March 1968 the Expedition has included five further phases, and finally terminated in September 1969, when the construction of a permanent research station began on the atoll. The first Director, Lt Cdr G. R. Lush, M.B.E., R.N., arrived to supervise construction of the laboratory and other buildings, together with a small assistant staff. It is hoped to have the Station functioning by June 1970, when places will be available for visiting scientists. Details of the facilities and of opportunities for fieldwork on this elevated atoll, which supports the largest population of the Giant Land Tortoise in the world (ARB 118: 1967), can be obtained from the Executive Secretary (ref. DJHG/ARB), The Royal Society, 6 Carlton House Terrace, London S.W.1. A liaison committee has been established between the National Academy of Sciences and Smithsonian Institution on the one hand and the Royal Society on the other to coordinate United States research proposals; this committee met in Washington for the first time in November 1969.

The following scientists have participated in Phases IV-VIII of the Expedition, in addition to those listed for earlier phases in ARB 126: 2-3. Some of these are visiting the atoll for the second or even third time, for long-term studies play an important part in the Royal Society's research program. Other scientists interested in following up particular lines of investigation are invited to correspond either with expedition members in the following list, or with the chief coordinator of the research program, Dr. D. R. Stoddart (Department of Geography, University of Cambridge, Downing Place, Cambridge, England), or with the Royal Society. The results of Phases I-III of the Expedition are now in press, and will be published as a volume of Phil. Trans. Roy. Soc. B during 1970.

Phase IV lasted from April to July 1968; Phase V Aug.-Nov. 1968; Phase VI Dec. 1968-Feb. 1969; Phase VII Feb.-June 1969; and Phase VIII June-Sept. 1969. During Phase V a visit was made to the atoll by the Chairman of the Aldabra Research Committee, Prof. T.S. Westoll, F.R.S.; the Director of the Nature Conservancy, Dr. M.E.D. Poore; and the overall leader of the Expedition, Dr. D.R. Stoddart.

W. J. Barnes, 34 Willowtree, Gilesgate Moor, Durham. Phase VI. Diving assistant and engineer.

Dr. C. J. Bayne, Museum of Zoology, University of Michigan, Ann Arbor, Michigan, 48104, U.S.A. (formerly The Marine Sciences Laboratories, Menai Bridge, Anglesey, Wales). Phase V, Aug.-Sept. 1968. Shallow water mollusca.

Dr. D. J. Bellamy, Department of Botany, University of Durham, South Road, Durham, England. Phase VI (leader). Reef front biota; phytosociology of land vegetation.

Dr. C. J. R. Braithwaite, Department of Geology, The University, Dundee, Scotland. Phase VIII. Mainland geology.

K. M. Brander, Fisheries Laboratory, Ministry of Agriculture, Fisheries and Food, Lowestoft, Suffolk, England (formerly Marine Science Laboratories, Menai Bridge, Anglesey, Wales). Phase V. Shallow-water polychaetes; plankton; studies of colonization of shallow-water marine substrates.

A. W. Diamond, Culterty Field Station, Newburgh, Aberdeenshire, Scotland. Phase VII (extended until Sept. 1969). Sea birds (continuing studies in Phases I-III).

Dr. E. A. Drew, Gatty Marine Laboratory, The University, St. Andrews, Scotland. Phase VI. Reef front biota, coral symbionts.

Dr. G. E. Farrow, Department of Geology, The University, Hull, England. Phase V. Growth increments in Tridacna; studies of geology of the elevated limestones; biogenic structures in soft substrates.

J. G. Frazier, Department of Zoology, University of Oxford, England. Phase VIII, extending to June 1970 (continuing work from Phases III and IV). Tortoise behavior, marine turtles.

J. C. Gamble, Marine Science Laboratories, Menai Bridge, Anglesey, Wales. Phase IV, remaining until Sept. 1968. Shallow-water mollusca.

R. D. T. Gaymer, Department of Zoology, The University, Bristol, England. Phase VIII. Problems of tortoise marking.

J. W. T. Grinter, 1 Prince Charles Flats, Ball Street, Paceville, Malta. Phase VII. General assistant.

Dr. R. N. Hughes, Dalhousie University, Halifax, Nova Scotia, Canada (formerly Marine Laboratories, Menai Bridge, Anglesey, Wales). Phase IV. Shallow-water marine biota.

W. F. Humphreys, Anti-Locust Research Centre, College House, Wrights Lane, London, W.8, England (formerly Marine Laboratories, Menai Bridge, Anglesey, Wales). Phase V. Shallow-water Echinodermata, especially ophiuroids; subsidiary study of leaf litter fauna.

D. J. Jones, Department of Botany, University of Durham, South Road, Durham, England. Phase VI. Reef front zonation; coral morphology in relation to currents.

Dr. W. J. Kennedy, Department of Geology, University of Oxford, England. Phase VIII. Mainland geology.

L. Kenyon, 37 Cranley Gardens, London, S.W.7, England. Phase VI. Underwater cinematography.

Dr. R. Lowery, Department of Zoology, Sir John Cass College, Jewry Street, London, E.C.3, England. Phase IV (leader). Blood parasites.

Dr. J. N. Lythgoe, Medical Research Council Vision Research Unit, Sussex University, Brighton, England. Phase VI. Fish zonation, behavior, and underwater vision.

A. A. Q. R. McLeod, Marine Science Laboratories, Menai Bridge, Anglesey, Wales. Phase V. Shallow-water Crustacea, especially Grapsus strigosus.

Mr. M. J. Penny, I.C.B.P., c/o Department of Agriculture, Victoria, Mahé, Seychelles (formerly Wildfowl Trust, Slimbridge, Gloucestershire, England). Phase VII (continuing from Phases I and II). Wading birds.

Dr. G. W. Potts, The Marine Laboratory, Citadel Hill, Plymouth, England. Phase V (leader). Fish ethology, concentrating especially on Labroides dimidiatus.

Dr. C. R. D. Reynolds, Department of Zoology, The University, Edinburgh, Scotland. Phase VII. Polymorphism in Littorina.

Dr. J. D. Taylor, Department of Zoology, British Museum (Natural History), Cromwell Road, London, S.W.7, England. Phase VIII (leader) (continuing work from Phases I and II). Land geology, especially paleoecology of marine mollusca.

S. Trudgill, Department of Geography, The University, Bristol 8, England. Phase VIII. Limestone solution rates and forms.

Dr. B. Whitton, Department of Botany, University of Durham, South Road, Durham, England. Phase VI. Reef-front biota; terrestrial blue-green algae.

ALDABRA NEWSLETTER, MARCH 1970: The Royal Society's Aldabra Committee has initiated a mimeographed newsletter which appears from time to time, to carry information of interest to those working on or interested in Aldabra. In this issue are notes of various sorts, of the general range covered by the news and literature sections of Island News and Comment of ARB. We will try not to duplicate or overlap except in matters of interest to a significantly wider audience than those concerned with Aldabra. Important in this issue is an appeal for books and reprints for the library of the new Aldabra Research Station and a list of items already contributed. Construction on the station is proceeding, but with usual delays and difficulties.

FRENCH NUCLEAR TESTS AT MURUROA, TUAMOTUS: During 1968 France exploded three atomic bombs (July 8, July 16, August 4) and two hydrogen bombs (25 August, 9 September) at her testing grounds in the eastern Tuamotus. A recent paper in Nature has reported the arrival of fresh

fission products from these tests in Japan, and it is interesting to note that the average speed of movement of the material in the atmosphere was about 12 km/h. This is comparable with the mean speed of the typhoons reaching Japan in August and September. These results are reported by T. Sotobayashi, T. Suzuki and A. Furusawa: "Inter-hemispheric transfer of fresh debris from French nuclear test in 1968", Nature, 224: 1096-1097, 1969.

According to a newspaper announcement, the French detonated the fourth in their current (1970) series of test shots on Mururoa in late June.

NOEL KRAUSS, Honolulu entomologist, writes that he has just returned from seven months general insect collecting in the Society Islands, Samoa, Tonga, Fiji, Gilbert Islands, Ellice Islands and the New Hebrides. The collections will be deposited in the Bishop Museum. We have received from Mr. Krauss a series of valuable bibliographies on some of these island groups. They were published by and are obtainable from the author.

NEW RADIOCARBON DATES FOR CORAL REEFS: Volume 11 (1969) of the journal Radiocarbon contains a number of reports of new radiocarbon dates from coral reef areas which bear particularly on problems of relative movements of land and sea in the late Pleistocene and Holocene. J. D. Buckley and E. H. Willis (pp. 53-105) report dates from Isotopes Inc., which include a series from slightly elevated conglomerate platforms and from reef flats at islands in the western Pacific (Ailinglapalap, Truk, Lukunor, Pingelap, Kusaie, Ebon and Jaluit). Dates from conglomerate ledges between 0.3 and 1.6 m above modern reef flats cluster between 1880 and 3250 yr BP. A further date, reported by B. Marsters, E. Spiker and M. Rubin (pp. 210-227) from U. S. Geological Survey determinations, gives an age of 2140 ± 200 yr BP for elevated reef at 0.6 m on Ifaluk Atoll. All these dates could be taken as confirmation of the hypothesis of a Holocene high stand of the sea: quite different interpretations have, however, been offered (see F. P. Shepard et al., Science, 157: 542-544, 1967, and J. I. Tracey, Jr., in U. S. Geol. Surv. Prof. Paper 600-A: 80, 1968).

An extremely interesting series of dates is provided by G. Delibrias, M. T. Guillier and J. Labeyrie (Gif Natural Radiocarbon Measurements III", pp. 327-344) for the upper portions of the Colette and Anemone boreholes at Mururoa Atoll in the Tuamotus. Only brief summary accounts of these boreholes have so far been published in C. R. hebd. Seanc. Acad. Sci., Paris, 263: 1946-1949, 1966 and 265: 1113-1116, 1967 (see also several papers in Cahiers du Pacifique 13: 47-74, 1969). The dates between 1 and 6 m depth cluster between 5000 and 6000 yr BP, with samples deeper than 7 m giving dates of 17,300 ± 800 yr or much older. These results are interpreted to indicate an old reef surface at -7 m, independently dated by uranium-

series methods at 120-160 thousand years BP. This surface was submerged at 8000 BP, and at about 5500 BP sea level rose rapidly from -6 to -1 m. One sample from Colette at + 0.8 m gives a date of 3020 ± 200, and one from Anémone at + 3 m a date of 3610 ± 200 yr BP. Again these appear to indicate a Holocene transgression.

Finally, a series of dates are reported by H. A. Polach, J. Chappell and J. F. Lovering (pp. 245-262) for samples from a suite of elevated reef terraces on the Huon Peninsula, New Guinea. Dr. Chappell believes that the width and height of individuals terraces results from interference or reinforcement between the continuous tectonic rise of the land during the Pleistocene and the eustatic variation of sea-level during this time. The first raised reef at c. 5 m is dated at roughly 6-7000 yr BP, the second at 20-23 m at c. 29,000 yr, and the third at 31-35,000 yr BP. Many of the older, higher samples, particularly of coral, yield anomalously young dates on account of recrystallization, and a study of this phenomenon is in preparation.

"OFFICIAL" TERMINATION OF PACIFIC OCEAN BIOLOGICAL SURVEY PROGRAM: From early 1963 through June 1970, the Department of the Army funded the Pacific Ocean Biological Survey Program which was administered through the Smithsonian Institution (see ARB 108:1, 1964 and 112:14, 1965). In addition to the major area of interest in the central Pacific, the Pribilof Islands in the Bering Sea, the Gulf of Panama and the islands and their surrounding waters off the coasts of California and of Baja California were surveyed. Field work was undertaken by sixty-one men, many of whom are determined to continue working with the data after funds run out on 30 June 1970.

In order to ensure continuity and no duplication of effort, work will be coordinated through Dr. Philip S. Humphrey, Director, Museum of Natural History, Lawrence, Kansas, for the next five years. The data assembled, and the zoological collections (birds, fishes, molluscs, reptiles, mammals, bird ectoparasites and some insects) will be kept at the Smithsonian Institution, and access to the data will be through Dr. Humphrey for the next five years, and to bird skins for the next two. The plant collections are held in the Department of Botany, University of Hawaii until duplicates can be distributed to other herbaria. In addition to the three Pacific Program contributions in this issue, we have published Bulletin 127: 1969 and anticipate publishing several more in the future. We plan also to keep ARB readers informed of publications and other activities that arise from the work of the project and the data accumulated.

PUKAPUKA (DANGER IS.): A correspondent in the Cook Islands writes that an Agriculture officer has visited Pukapuka, "carrying gallons of Dieldrin and Aldrin for spraying around coconut trees in Pukapuka. The palms are infested with termites which arrived in the Cook Islands from Australia in soil imported by Lever Brothers in 1904. Soil was brought to Suvarov, also to Nassau, Palmerston, and now Manihiki.

"What will be the runoff into the lagoons and reefs from these chemicals? Gallons and gallons are being sent, and apparently a large lot of the poison was sent several months ago. Can you imagine what this will do to the marine ecology around the atoll--the ecology of which is vital to a people almost entirely dependent upon it?....
"The amount of chemicals used there as far as I can determine was

5 gallons Aldrex (Aldrin) 20% emulsion
5 gallons Dieldrin (oildrex) 15% solution emulsion
50 lbs. Oildrex Dieldrin wettable powder 50%

"Perhaps with the sophisticated computers you people have up there you can work out probable effects on lagoon and reef life from the size of the island and lagoon. As far as I can tell the chemicals are mixed in 50 gallon drums diluted 2 tablespoonsful per gallon for dieldrin powder or 2 dessert-spoonsful per gallon for the emulsion, then sprayed at the base of all infected trees. Tree infection is 50%--and there are of course thousands of trees. Aldrin is used the same way."

RESEARCH AT HERON ISLAND: Research now in progress at the Heron Island Research Station on the Great Barrier Reef includes a study by Peter F. Sale of the School of Biological Sciences, University of Sydney, of the common Barrier Reef pomacentrid fish *Dascyllus aruanus*. Mr. Sale is investigating habitat selection by this species, and the behavioral mechanisms involved in it, with field observation complemented by laboratory experiment. The project began in November 1968.

STEVE DOMM, formerly at Heron Island, writes from Sydney that he is "temporarily working at the Australian Museum learning to identify most of the larger fishes of the southern Great Barrier Reef and doing some work on the Museum's coral collection to deepen my knowledge of corals based on 3 years field experience. I am currently working on papers concerned with the distribution of some fishes on the lee and windward of a reef and the different growth rates and forms of some corals on the lee and windward of a reef. I am awaiting the outcome of several grant proposals, which if successful will enable me to live on One Tree Island and with others from the Australian Museum study various aspects of reef ecology. We are also interested in making a study of the before and after effects on the fishes and corals resulting from a Crown-of-thorns (Acanthaster) attack."

REGIONAL VARIATION IN INDIAN OCEAN CORAL REEFS was the subject of a symposium held on May 28-29, 1970 at the Zoological Society, Regent's Park, London, sponsored jointly by the Royal Society and the Zoological Society. Sir Maurice Yonge and Dr. David Stoddart organized the symposium. There were participants from a number of countries, including Germany, France, India, and the U.S.A., as

well as Great Britain. Among other points, it was brought out that present records indicate a world maximum of coral genera in the western Indian Ocean, centering on Aldabra. This would seem to be more an indication of where collecting has been thorough. Papers were read on geomorphology as well as on biology and biogeography.

SECOND INTERNATIONAL SYMPOSIUM ON CORALS AND CORAL REEFS: Discussions are in progress between the Committee for International Symposia on Corals and Coral Reefs, the Great Barrier Reef Committee, and the Australian Government on the possibility of holding this symposium at the Heron Island Research Station, Queensland, Australia in August 1972. The Great Barrier Reef Committee has offered to act as host organization. We will publish further announcements on this as news becomes available.

INTERNATIONAL BIOLOGICAL PROGRAM: A memorandum dated June 13, 1969, circulated by Sir Maurice Yonge, points out that "coral reefs represent a 'Theme' within the Marine Section (PM)" of IBP, mentions three recent symposia held on topics related to coral reefs, and indicates that future symposia and field studies are planned by the PM section, in cooperation with other activities and expeditions. Information may be had and comments addressed to Sir Maurice Yonge, 13 Cumin Place, Edinburgh 9, U.K.

ENIWETOK TRIP: The Smithsonian Institution is unique in possessing a large corps of natural historians capable of studying all aspects of biological and geological oceanography and relating them to the marine ecosystem. Whereas interface research and free exchange of ideas between individuals is commonplace within the Institution, field symposia which bring together scientists of diverse disciplines have been few and restricted in scope. Development of the concept of an underwater seminar with participants representing diverse fields of biology and geology therefore constitutes a necessary and important step forward in the study of marine ecosystems.

In September of 1969, seven Smithsonian and Geological Survey SCUBA divers, specialists in fossil and living Molluscs, Echinoderms, Brachiopods, Arthropods, and environmental systems, joined specialists in marine Bryozoa and reef fishes from Penn State and Gulf Research, respectively, to participate in the first underwater seminar sponsored by the Smithsonian Institution in cooperation with the Atomic Energy Commission and the University of Hawaii. The site chosen for the study was Eniwetok Atoll in the Marshall Islands, a location with many unique advantages and well suited for our purposes. Eniwetok is typical of large Pacific Atolls in every way, and part of it has been set aside as a marine biological preserve. A significant contribution to our ecological knowledge of the atoll could be made in the time available. In addition, specialized studies of current interest--the Pacific starfish (Acanthaster) problem and possible latent effects of nuclear testing--could be meaningfully studied. Excellent logistical support

is available from the Air Force contingent on Eniwetok Island and its contracted support group, Kentron, Inc. All base facilities are freely available to visiting scientists. Adequate housing, good food, medical and laundry services, a vehicle, and various diving boats (staffed) capable of handling a large group were provided to us. In addition, we received the highest degree of cooperation from the commercial diving corps of Kentron, members of which accompanied us on trips as guides and backup safety divers, filled air tanks daily for the group, and provided backup equipment and repair facilities. The Eniwetok Marine Biological Laboratory, though poorly managed at the time, provided adequate research facilities, including salt water aquaria, for basic behavioral studies, specimen preservation or dissection during non-diving time. Consequently, each scientist's time could be fully applied to his studies in an efficient manner, and maximum information obtained for the short duration of the visit. Finally the relaxed, informal atmosphere of the entire operation was conducive to frequent and meaningful exchange of observational data and ideas, and to the construction of concepts regarding characteristics of various marine environments, organism adaptation to environmental parameters, community structure, and the total ecology of the atoll.

A typical seminar day began with breakfast at 6:30, followed by equipment check and loading for an 8-9 A.M. departure in the diving boat. Discussion on the way to the site centered around the expected environmental parameters of the location, organization of the dive, and individual research needs for the particular environment. The morning dive was commonly the deepest of the day, between 50 and 100 feet; the afternoon dive was the shallower but longer effort. Each dive was designed to test a different environment of the atoll, and the trip was long enough so that all major environments were sampled. Immediately after a dive, specimens were sorted, live individuals placed in aquaria, and other material sorted and passed around so that each scientist could observe the whole aspect of the fauna on a reef block or bottom sample, and then retrieve from it individuals within his speciality. Commonly a single reef block from, for example, a deep cave environment would provide interesting material for all scientists on board. In long discussions following each dive, the general characteristics of the selected environment, the functional morphology of organisms adapted to it, various diving experiences, and the composition of principal communities were reviewed--an extremely rewarding experience. The diving boat returned at 5 P.M., specimens were transferred to live tanks at the marine lab, and equipment washed and checked before dinner. Most evenings were spent in group discussion of the day's observation, or in the lab watching behavioral patterns of living specimens, identifying, preparing and packing specimens, and completing notes on the day's activities.

Preliminary results of the trip speak highly for the whole concept of the underwater seminar and suggest that this could be repeated in different areas with considerable impact on the experience of the staff.

All major atoll environments except deep lagoonal muds were examined and sampled by the entire group, and communities of macroorganisms broadly defined within them. In situ behavior of numerous organisms was recorded, and their adaptive features defined within the environment. For all sites, sediment samples were taken for microorganisms, as geological data defining sedimentary parameters, and as a test of the reflection of living communities in dead shell assemblages on the bottom--the potential fossil record. In two weeks the principal components of the biota were observed, and in some cases as the molluscs the known fauna for the Atoll was increased more than one-third. Rare discoveries include abundant brachiopods, bryozoans, and crinoids associated with stromatoporoid sponges and green algae in deep reef-face caves, and a bivalved gastropod. But the most meaningful result is a considerably broader comprehension of the interactions of organisms within the environment--the reef ecology--that every specialist took away with him. No other mean of communication between scientists has proven as effective as joint field experience such as this, and we highly recommend its perpetuation.

Several of the staff participating in the trip are planning or actually working on published or summary reports of their findings. The greatest recommendation for the concept of the underwater seminar is the fact that in two weeks of working and observing together, asking questions and proposing ideas, we learned more about the broad aspects of reef ecology and organism distribution than can be found in the compiled literature of the Pacific Islands.

E. G. Kauffman

ADVANCE REPORT ON THE FAIRBRIDGE NEW GUINEA CORAL REEF EXPEDITION: We have carried out (February-May 1969) a running reconnaissance, using two vessels (a 65-foot trawler and 42-foot launch), of the reefs and lagoons of the Trobriand Islands, Lusancay Group, D'Entrecasteaux Islands, the Louisiade Group (including the Conflict Group, Deboyne Is., Misima, Rossel and Tagula) and parts of the Papua Barrier Reef. We estimated that about 800 nautical miles of linear reefs are involved in this area east of New Guinea. The area covers about 75,000 square miles. Up till now there has been no oceanographic, geomorphic and ecologic survey of any of these reefs. Five hitherto unnamed and unmapped islands were discovered.

We carried out the following routine observations:

1. Bathymetry. Within reef lagoons, spot depths were obtained by echosounder approximately every 0.5 nautical mile. (Continuous recording was not possible on the simple type of equipment available.) Specifically in the Lusancay Group, in the Long Reef atoll and in the Conflict Group there were hitherto almost no soundings until now. Detailed tracings will be submitted.

2. Water temperature and salinity. Readings were made systematically throughout the expedition, and complete tables will be submitted.

3. Sediment samples. In every lagoon Petersen grab samples were obtained, wherever possible, where different lithologies were observed. Samples are being quartered and one complete set will be submitted. Sedimentological analyses are in progress. Some coring was attempted, but not very successfully owing to the coarse nature of most lagoonal floors.

4. Coral and other reef life. Organisms were collected systematically and ecologic traverses were made across reefs whenever conditions were suitable. Samples are now under study.

5. Fish. A representative of the Sydney Museum collected fish for taxonomic purposes and will report on them. The Director of Fisheries of the Papua and New Guinea Administration accompanied the expedition for most of the period and made observations on commercial fish potentials. Specific search was made for evidence of fish poisons. Two cats were kept as "official tasters." Not a single case of poisoning was obtained, although interrogated natives reported occasional cases in the regions. No systematic pattern emerged, but the details will be reported.

6. Hazards. (a) Shark: a masthead watch was maintained at all times when skin divers were in the water, and frequent sightings were made in the deeper channels. Most of the lagoons seemed to be rather shark-free.

(b) Stone-Fish: care was taken by divers to wear heavy gloves and rubber shoes and usually to carry a fish spear. Stone-fish anti-venin treatment was kept ready on both vessels, but no strikes were suffered.

(c) Portuguese Man-of-war : no trouble was experienced with stinging jelly-fish, which were locally reported to be hazardous at certain seasons.

(d) Coral poisons: with care (gloves, shoes, rubber wet suits, for exposed areas) coral stings and abrasions were kept under control, but could not be avoided completely. Slow healing of wounds was noted, as expected, in spite of the best medical treatment.

(e) Sea snakes: a specialist herpetologist joined the expedition to collect poisonous sea snakes. At all times anti-venin was kept available but no bite was received. A large number of snakes were captured alive and are now being studied.

(f) Crocodiles: these reptiles are no problem on the reefs and sand cays, but in spite of hunters are still quite numerous in the mangrove. An 18-year old girl was taken near our base on Kiriwina. They are hard to identify in daylight but at night the red eyes reflect flashlight beams.

A detailed scientific report is in preparation.

Rhodes W. Fairbridge

Prof. Fairbridge has kindly sent, also, a copy of his fascinating log of the expedition. It is very interesting reading and contains much geographical information, in addition to the day to day happenings of the expedition.

COMORO ISLAND BIRDS: We received the following letter and publish it for whatever interest it may have for our ornithological readers:

"In Atoll Research Bulletin No. 128 of August 15, 1969, A. D. Forbes-Watson gives as a new record of Fregata ariel [in the Comoros] on the basis of a sight record of a pair seen on 20 October, 1965, at Moheli.

I should like to draw attention to my paper "Observations by personnel of R. V. Atlantis II on islands in the Indian Ocean" published in "Sea Swallow", the Annual Report of the Royal Naval Bird Watching Society for 1967 in which two male Lesser Frigatebirds Fregata ariel and one female, seen in May 1965 at Grand Comoro, are reported. Between Grand Comoro and Mayotte we also saw a pair of Greater Frigatebirds Fregata minor, so it appears that both occur in the Comoros as they do at Aldabra, the nearest likely breeding station. Lesser Frigatebirds were also common about Nosi Be, Madagascar, and I believe that Michael Palmieri, our Third Officer, and an Honorary Investigator for the Smithsonian, collected some for George Watson, then of the Division of Birds.

You might not have heard of "Sea Swallow" but it would probably be of interest to readers of the Atoll Research Bulletin as articles appear on visits by Navy personnel and sea-going scientists to islands throughout the world and the coverage of oceans makes it invaluable to ornithologists with an interest in sea-birds. It is obtainable from:

The Editor, "Sea Swallow",
8 Little London,
Chichester, Sussex, England

Yours faithfully,

Roger Pocklington
Bermuda Biological Station for Research

DEATHS: It is with deep regret that we have to announce the passing of eight of our friends and colleagues during the last several months.

Dorothy Carroll, eminent sedimentologist of the U. S. Geological Survey and co-author of ARB 113, died in January 1970. Her career began in Australia, but for over 15 years she was on the staff of the Survey, first in Washington, then in Menlo Park. She was a master

of analytical techniques for dealing with sediments and set up a sedimentology laboratory for the Survey.

Charles G. Johnson, geologist of the U. S. Geological Survey, for the last several years stationed in Denver. He had wide experience in Pacific geology and worked in the field in the Marshall Islands with the senior editor in 1956. A better companion for field work would be hard to find. His untimely death occurred December 1, 1969, at the age of only 55.

Mark Veevers-Carter, lessee of Astove Atoll, and enthusiastic island agriculturist, died in Mombasa in March. He had a deep practical knowledge of coral islands, was Director of Agriculture in the Seychelles for some time, lived on Remire Island for several years, and for the last several was attempting to make a flourishing farm and livestock establishment of Astove. Our deepest sympathy is extended to his widow, Wendy, and their children. We have not heard if they will stay on Astove.

Floyd A. McClure, universally acknowledged world authority on bamboos, died of a heart attack in his bamboo garden on April 15. He was always ready to help us with those refractory members of island floras, the bamboos, and was working on those of Ceylon, in collaboration with Tom Soderstrom at the time of his death. In addition to losing one of the most able and scholarly of botanists, we have lost one of the most gentle and admirable of men and one of the finest of friends. He was that rare sort of person, one with neither critics nor enemies.

Thomas Goreau, physiologist and scuba-diver extraordinary, and student of a new biotope--the deep outer slopes of coral reefs, failed to survive serious surgery followed by pneumonia on April 22. He was only 45 years old, but had established a world-wide reputation as a leading investigator of coral reefs. He brought a profound knowledge of physiology, adeptness in radio-isotype techniques, tremendous energy, and a scientific imagination of a high order to the field of reef biology. A fearless diver, almost to the point of undue risk-taking at times, he showed us that the deep outer slopes of reef islands had many secrets to be won by the courageous. He worked in Jamaica, in the Pacific, and in the Red Sea, amassing information of many kinds, all too little of which ever saw publication. He drove himself unmercifully, but insisted on a thoroughness that inevitably cut down his published output. His shoes will be hard to fill. Our deepest sympathies go to Nora, his widow, and we hope she will be able to see some of his unfinished work through, as she is an eminent physiologist in her own right. Above all, we feel the loss of a great friend.

Only a month before his death he had seen the realization of one of his dreams, the opening of his own marine laboratory by the University of the West Indies and the University of the State of New York, Stony Brook, in both of which institutions he held chairs. We hope this facility will develop as a fitting memorial to him.

Professor Hisakatsu Yabe died on 23 June 1969, at the age of 90 years. Professor Yabe made many contributions on the geology, palaeontology and geomorphology of coral reefs, both fossil and modern, in the Japanese islands and in the former Japanese mandate islands of the western Pacific. Most of his coral papers appeared after 1932, and in 1937 he made an extensive tour of western Pacific coral islands. Much of this work was published in collaboration with such workers as M. Eguchi, S. Hanzawa and R. Tayama. Perhaps Professor Yabe's best-known and most valuable contribution to reef studies was his systematic treatment of western Pacific corals published with T. Sugiyama, "Recent reef-building corals from Japan and other South Sea islands under the Japanese mandate", which appeared in two parts as Special Volume No. 1, Scientific Reports, Tohoku Imperial University (Geology), in 1936 and 1941, with 155 plates. There is an obituary of Professor Yabe by K. Hatai, including a bibliography of 394 papers, in Sci. Rep. Tohoku Univ. 2nd ser. (Geol.), 41(2): 109-128, 1969.

Chester K. Wentworth, eminent geologist and remarkable man, student of, among many things, island geological phenomena and processes, author of the geology of the Whippoorwill Expedition to the Line Islands, 1924, died on January 6, 1969, after a long crippling illness. A memorial of his life and work, and a partial bibliography of his papers, by Gordon A. Macdonald and Doak C. Cox was published in the Proceedings of the Geological Society of America, November 1969.

Dr. F. A. McNeill, co-author with Keith Gillett of "The Great Barrier Reef and adjacent isles" (Sydney: Coral Press Pty. Ltd., 1959) and for several decades a member of the staff of the Australian Museum, Sydney, died on 24 February 1969. His colleague G. P. Whitley contributes a brief memoir to the Australian Zoologist, 15: 214-223, 1969, together with a very full bibliography covering Dr. McNeill's many popular magazine articles on Barrier Reef topics, as well as his scientific papers. Some 175 items are listed. Dr. NcNeill was a member of the Great Barrier Reef Expedition of 1928-1929, and one of his last works was a report on the "Crustacea, Decapoda and Stomatopoda" of that Expedition (Sci. Rept. Gt. Barr. Reef Exped. 1928-1929, 7: 1-98, 1968).

SHORT PAPERS

MAPPING REEFS AND CAYS, A QUICK METHOD FOR THE SCIENTIST WORKING ALONE

by S. B. Domm

Introduction. In the absence of aerial photographs, the methods commonly used to map cays and small reefs are either the use of the plane table or chain and compass traverses. The former requires the use of at least two persons and the latter, while it can be done by one person, is time consuming and not suitable for mapping a reef which may be awash or underwater.

While working on the Great Barrier Reef of Australia, I have developed and used a method which is not really new, but does not appear to be well known. It enables one person to quickly map an area of up to approximately one mile across (perhaps even more), using equipment that is commonly available and relatively inexpensive. Being light weight and also highly portable is also a feature of the equipment used. The method requires relatively open country and does not take into account differences in height. The accuracy varies, but is easily capable of producing a good field map.

Equipment. The following items comprise all the equipment needed: (1). A pair of binoculars or a telescope in which have been fitted a graticule or parallel cross hairs. This is usually done by having one etched on a small glass disk, which can be fitted behind the eyepiece and removed when not needed. The intercept of the graticule can be any desired size, however possibly the most useful would be a graticule interval of 1' to 100' which is commonly used with most plane table alidades. This means that when sighting on a foot graduated stadia rod (or staff), one foot as seen through the instrument (exactly the interval between the hairs of the graticule), equals 100' in distance from instrument to staff. The graticule interval can be anything, so long as the staff is graduated accordingly. The greater the distance the larger should be the interval, as it can be very difficult to distinguish small intervals at distances of over about half a mile.

The power of the telescope or binoculars depends on the distances that will be encountered when mapping. I use a pair of 20 X 50 binoculars (used normally with the graticule removed) and find them very good for sighting up to approximately half a mile. The graticule used is one giving 22.5' distance when sighting one foot on a staff, this is not ideal but was all I could obtain at the time. The telescope or binoculars must be used with a tripod, a light camera tripod being adequate.

(2). Prismatic sighting compass. For ease of reading I use a standard marine hand-bearing compass.

(3). Staff (stadia rod), can be either a standard surveyor's type, graduated in feet and tenths, or a home made staff with the desired graduations painted on. The staff could be in the form of two or three metal pipes telescoping into each other which could be expanded in the field and locked into place. Some method is necessary to hold the staff upright in a fixed position and a small spirit level is useful to help place it vertically.

(4). Hard-backed field note book and pencil.

Method. It is almost the reverse of using a plane table, in that the staff is used as with the plane table to determine the horizontal distance, but here the staff is permanently placed at the approximate center of the area to be mapped, and the person doing the mapping moves around the fixed staff. The staff and binoculars are used to determine the distance and the hand bearing compass to give a direction for each distance.

An outline of the method is a follows: given a sand cay covered by low vegetation to be mapped. To be included in the map are various topographical features, such as clumps of trees, depressions, etc. The diameter of the cay is approximately half a mile. First, the staff is set up near the center of the cay, or if the cay is large it is mentally divided up into sections and the staff fixed near the center of the first section. The staff is either tied to a tree or held in position with lines, and is as close as possible to being vertical. After the staff is in position one commences mapping from any convenient location (a clump of trees, the periphery of the cay, etc.). The proceedure is to first take a sight on the staff and record the intercept, then sighting the staff, its bearing is recorded, and finally any notes concerning natural features are also recorded. In a few minutes one has recorded distance, direction and comment. In this way one moves slowly around the cay mapping all features that are to be included in the map. An example of the first entry into one's notebook might be:

Station			
1	2.3	187	Sandy beach begins here.

If it becomes necessary due to increasing distance or blind spots because of vegetation in front of the staff, the staff can be moved. A suitable location is found and the distance and bearing are recorded of the first location from the proposed second location. The new location is then marked and the staff re-erected here. The mapping continues by sighting on the new position using a different numbering system to indicate that this is the second staff position.

The result is a book containing data that can be easily turned into a map by plotting on a large sheet of paper. The accuracy depends upon the instruments used and the care taken in making observations. Reading the staff can be difficult, especially if a wind causes it to sway. Under such conditions much care should be taken in siting the staff in a favorable location, or fixing it securely in place.

Magnetic north is easily determined from any of the bearings and true north by applying the appropriate variation to this. Plotting the data and drawing the map can be done at any time. After determining the scale desired on a sufficiently large piece of paper, the first staff location is indicated by a small dot, and the stations are drawn from this as a series of radiating lines. As each line is drawn, the distance is worked out from the stadia intercept and marked on the line. When all the lines are drawn the outline is sketched in (using the field comments to fill in) revealing the finished map when all is done.

Mapping a reef can be more difficult. If it has a lagoon the staff may be located on a patch reef within the lagoon. Mapping can be done either at low tide by walking around the reef margin, or during approximately mid-tide (with no more than about 2 1/2 feet of water over the reef) by traveling by small boat and landing at various intervals on the reef to take sights of the staff from the reef. Due to the constant movement, sighting from a small boat is seldom practicable. On windward parts of a reef it will usually be necessary to map only during low tide when one can walk on the reef.

This mapping method does not take into account any differences in elevation. Sand cays and coral reefs are usually very low structures having little relief, therefore this shouldn't seriously affect the overall usefulness of the method.

Working alone, I have found this method of mapping to be quick and reasonably accurate. A further advantage is that it doesn't require any specialized or expensive equipment. High powered binoculars are a standard research tool and a hand bearing compass is a common item of marine equipment. However, I experienced difficulty in having a graticule of the desired intercept fitted to a pair of binoculars. If the fitting is of a permanent nature it still shouldn't drastically interfere with the normal use of the instrument.

ISLAND CONSERVATION: Following are two short essays on conservation from Micronesia, which indicate a local appreciation of the values at stake as small islands are being "developed", dragged willy-nilly into the torrential stream of Western culture that threatens to overwhelm the world. Mrs. Falanruw, born in Guam, is an instructor in the Biology Department, University of Guam, Agaña, Guam. Mr. Kochi, native of Palau, is conservation officer, Palau District, Trust Territory of the Pacific Islands. We thought that our island readers might appreciate the thinking of two of their colleagues from Micronesia.

Conservation in Micronesia. Some people may feel that pollution, overpopulation and conservation are problems of the outside world which have not reached Micronesia. This is a dangerous belief as many of these problems are already upon us. We must become concerned now, for our land is so very small that we cannot afford to make ecological mistakes. On continents people have had at least a chance to learn from their mistakes, on our small islands, mistakes may bring immediate dire consequences. We have only one chance...

Now is the time to look at the problems of others and learn from them before we make the same mistakes in our own beloved Micronesia. Much of our island world is still in a relatively clean, productive state. Let's look ahead and keep it that way--other people do not have such a bright prospect.

There has been much talk about the political status of the Trust Territory. Whatever the peoples' choice, Micronesian integrity must be dependent on some degree of self sufficiency, which in turn is dependent on the utilization of indigenous resources. Micronesia is potentially a rich area. The coral reef is one of the most productive environments in the world biologically. Once our technology is developed enough to enable us to utilize this productivity Micronesian wealth will begin to be further realized. Let us learn to use our resources properly. Above all, let us not damage those resources before we learn how to use them.

It is generally held that Micronesian cultures were adapted to the island environment--how else could man have persisted on islands all these years. I feel that Micronesian cultures, at least in the past, not only allowed man to live on islands, but allowed islands to "live" with man--and so maintain their productivity for man's use.

Islands are fragile systems. They can be upset and their productivity greatly decreased. Their very life depends on a thin skin of living matter, coral polyps and cementing algae. Without the protection given by these organisms, the islands themselves would be washed away.

I have been told by a number of Micronesians that fish are not as plentiful as they once were. No one seems to know why. I think that this decrease in fish and other once more abundant resources can probably be traced to present day unwise use of the environment.

Why didn't this happen in the past? Certainly man has lived on Micronesian islands for thousands of years--and in some cases in very dense numbers. I feel that two factors are involved. First, original island man did not have a technology with which he could severely damage his ecosystem as he does today. He did however, have fire, poisons, and was in sufficient numbers to produce considerable wastes and compete with other life forms. It is possible that no other animal could have lived on islands in such biomass as early man. The reason

for this, and the second factor in the maintenance of a productive island ecosystem, I believe, is culture.

I believe that island man's culture formed a buffer between him and his environment, preventing him from destroying his island.

One of the most straightforward of island man's former practices keeping him and nature in balance was the limitation of the human population. If this was not done naturally by calamities such as typhoons, tidal waves, and droughts, it was done culturally by attempts at overseas voyaging, suicidal voyages, celibacy, prevention of conception, abortion, and infanticide.

Other cultural measures promoting the maintenance of a healthy island ecosystem were possibly the "conservation laws" of many islands. It is said that certain atolls or portions of islands were set aside to serve as reserves where turtles and other animals and plants might reproduce and thrive and so maintain their numbers. In some cases, bans might be put on harvesting in an area until it regained its former productivity. One such example is the "bungud of the lupuu" as is done on Yap. When fish become scarce and small, a sign is put up in the lagoon prohibiting certain kinds of fishing, or all fishing there. When fish have regained their former size and abundance, this ban is removed.

Some workers have suggested that the social structuring of islands is adaptive. Social structuring determines that some shall be supported better than others and that the island itself will not be damaged by over-exploitation of its resources.

Social stratification also results in a diversified use of the islands resources. If some items, such as turtles, are available only to the high classes while other foods such as eels are eaten only by low classes (as is the case in Yap), then both turtles and eels are protected from exploitation by all inhabitants of the island. This would tend to insure their continued productivity.

Another factor in making culture a buffer between man and his ecosystem is the complex way in which lands are held. Any number of people can have claims on a piece of land by virtue of living on it or cultivating it, or by possessing a name that goes with the land or by having one's ancestors born or buried on the land or by being a "father" type relative to a person having claim to the land, etc. Land ownership in Micronesia seems to have always been complex, and perhaps always a little disputed. This would seem to assure that the land could be used by a number of people and that it could not be over-exploited by any one person. The same situation would apply to the waters of the lagoon and near the reef as in many cases these waters, or fishing rights in these waters, belong to certain people.

There are other regulations requiring that property not be used for varying times after the death of a person connected with that property. This measure assures that land may lie fallow at times, an important factor in the maintenance of its productivity as well as the maintenance of a pool of "wild" elements in the flora and fauna.

How will these conservation practices be affected by the new land cadaster program and by the failure to acknowledge local ownership of lagoon waters?

It is doubtful that individual island inhabitants recognized that the social regulations of their culture were of ecological import. Certainly island man is not a frugal being. In fact, one of the few things that he strives for is to have an over-abundance of food. One of the most important things throughout Micronesia is to be able to throw a big feast. In planning this feast, one does not merely plan to have enough food but rather to have "too much enough." This abundance in the face of limited resources is truly a tribute to island man's ability to keep his balance with his island ecosystem.

Inasmuch as former conservation-valued practices were in the guise of religion, social stratification, taboos, etc., the young people of Micronesia today are not individually conservation-minded. Furthermore they live at a time when the populations of many islands are not as dense as they once were and resources appear to be relatively abundant. However the population of Micronesia is rapidly expanding, at a time when a higher standard of living is desired and at a time when ideals of equality of men are being promoted so that the former ways of life and social stratification will no longer exist to enable the island ecosystem to support as many people as it once did. The chances of destroying island resources loom ever greater.

It is essential to inculcate a sensitivity to the vulnerability of the island ecosystem into the present and future generations of Micronesians who once possessed such a cultural sense of conservation but who are in danger of losing it with the changing of their cultures. It is important that <u>individuals</u> come to appreciate the need for using their ecosystem wisely because, more and more, the way in which the Micronesian ecosystem is used will be a matter of individual choice.

M. Vernita C. Falanruw

<u>Objectives and importance of conservation</u>. I live in Iyebuki in Koror Town, but am more at rest in the forest, savannas, woods and jungle. I have a very personal relationship with the open land that I simply do not have with congested town surroundings.

I find rest and comfort in thicket and field--in the quiet rippling of a brook, the thundering solitudes of a waterfall, the silent scampering of woodland creatures, the calls of different birds, the sounds and the voices of nature that are apart from the things man builds and destroys.

I do need the great outdoors. So do we all--a fact often ignored as we stack population upon population in our town when thousands of every age compete for the limited green space available... as we seek to satisfy the compelling need for more space to grow in, without providing adequately for the protection and enhancement of the green and flowering lanscape that, once overrun, is lost.

Unless we develop and manage our land in harmony with nature we will live in barren communities.

We have the priceless Palauan heritage in the forest, savannas and the sea that belong to all the people. To assure that this great heritage is preserved, and denied to no one, is the primary responsibility of every individual citizen of Palau.

A bountiful and beautiful Palau is many things. It is the prosperity of its people...nature unspoiled and nature improved... well-tended forest, savannas, waters, all other resources, and a well-kept town... the spirit of a people intent upon improving life for themselves and for their children...all the accomplishments of individuals, private organizations, and governments.

In our designs for a more satisfying way of living, we must enrich our lands. We must:

1. Plant forests and improve existing woodlands and savannas.
2. Line the roadside and streambanks with grass and other foliage.
3. Build dams, and reservoirs for flood control, water storage, recreation, and for wildlife conservation.
4. Protect with terraces, and contour the agricultural lands, to stop erosion and to hold more water on the soil for better crops.
5. Secure the soil to the mountains and fields to keep rivers and streams free from silt and pollution.
6. We must know how to enhance the natural beauty of the forest, woodlands, terraces, savannas, and the sea while assuring a great bounty from the fields and the sea.
7. We must accomplish much which is beneficial through our use and conservation of the land and waters.

8. "Common Sense" must be used to know better from worse.
9. Stop pollution and use of dynamite that destroy marine life.
10. Clean garbage to reduce rat populations and avoid smells.
11. Prevent wildfire from destroying our lands.

Every responsible Palauan has his obligations as a conservationist. He must be born to the role. Even if he does no more than respect the natural landscape and the labor of those who work to maintain it, he is bound at least not to despoil nature's valuable gifts.

The "active conservationist" must be advanced beyond merely leaving nature alone and being careful not to thoughtlessly disturb it. Fortunately, more and more Palauans are becoming active conservationists--in their own yards and neighborhoods and in support of communities, villages, and also with efforts to make man's environment more attractive and pleasing.

If we do this, we will make our reward a rich one. We will have the satisfaction from playing a part in the continuing preservation and wise management of our cherished lands. Because our land is the provider of natural resources, we must realize that our great land is facing a more rapidly rising population than can easily maintain forest, and clean streams, rolling meadows, and carefully tended lands.

We all know man needs nature and nature needs man. So why don't we properly develop, preserve, and manage our land that it will be maintained intact in the long run into the future. This is the objective and work of conservation and wise use.

John S. Kochi

PUBLICATIONS

Leopold, E. B., Miocene pollen and spore flora of Eniwetok Atoll, Marshall Islands. Geological Survey Prof. Pap. 260-II: 1133-1185, pl. 304-311, 1969. We are delighted to see this long-awaited paper. In her very competent study of the micro-paleobotany of the deep drill-cores from Eniwetok, Estella Leopold has given us a glimpse back into the past of an atoll. Her interpretations of the pollen flora tell us a surprising amount about the conditions on the island during Miocene time. There seems little doubt that at certain periods the land surface was elevated well above the sea level. Plants grew there which are now found far to the west, only on land higher than sea level atolls. We have long had the idea that competent palynological studies are needed throughout the Pacific islands to elucidate floristic, phytogeographic and vegetational problems. This remarkable study makes this very clear and we hope that further development of capability for such work will take place in the immediate future.

Ladd, H. F., Tracey, J. I., Jr., and Gross, M. G., Deep drilling on Midway Atoll, Geological Survey Prof. Pap. 680-A: A1-A22, 1970. Harry Ladd may chalk up another in his string of major contributions to atoll geology with this paper. Two cores, through the limestone cap and into volcanic clays and basalt are described and their significance summarized in a section on Geological history of Midway. Subsidence of between 350 and 400 m, at least, is indicated, as in the basal clay are beds of lignite with abundant land-plant fossils. These are being studied by Estella Leopold and we expect another major addition to our understanding of the floristic and vegetational history of the Pacific Islands when her work is completed.

The introduction to the paper is a concise but very informative sketch of the regional geography and geology of the Leeward Hawaiian islands and of the Hawaiian region as a whole. The preliminary indications are that the lower limestones are of early Miocene age. At least 3 periods of emergence are indicated after the sea finally covered the volcanic rocks. Actually, the core diagram for the deeper "reef" hole, fig. 7, seems to indicate about 7 such emergences, but only 3 are mentioned in the geologic history, plus brief reference to two unconformities indicated in the diagram. Land shells (Endodontidae) were found between 137 and 165 feet depths.

The Hawaiian atolls have had a long and complex history, with great changes in local environmental conditions. Thus there have been ample time and suitable settings for much of the present complex Hawaiian biota to have evolved, perhaps even before the present high Hawaiian Islands had appeared. A bathymetric chart, plate 1, shows that the region of the Leeward Hawaiian atolls, rather than having a simple chain of 5 or 6 volcanoes now subsided to atoll status, comprises a whole swarm of ancient volcanoes mostly now indicated by seamounts, some of them flat-topped (guyots). The photos, including a beautiful colored air photo of the windward reef of Kure Atoll, and the maps and diagrams add enormously to the understandability of the paper.

Corner, E. J. H., ed., A discussion on the results of the Royal Society Expedition to the British Solomon Islands Protectorate 1965. Phil. Trans. R. Soc. (London) B, 255: 185-631, 1969. This magnificent and abundantly illustrated volume is a massive refutation of the idea that the day of expeditionary science as a productive endeavor is drawing to a close. The Royal Society Expedition to the Solomons was an impressive effort, involving 20 scientists, 3 local scientific visitors, 10 members of the ship's crew, and 35 local helpers in various ranks and categories. It lasted from June to December, 1965, visited 8 large islands or groups, and collected and studied most land and marine groups except the land vertebrates, fungi, and terrestrial microscopic algae.

This volume includes the proceedings of a three-day symposium held under the auspices of the Royal Society, March 27-29, 1968, to present in brief form the results of the study of collections and observations made by the expedition, and to discuss their ecological and biogeographical significance.

In all, 30 papers were presented and they are printed here with transcriptions of extensive discussions. The papers were grouped into a section on the general environmental characteristics, one on the land fauna, one on the marine biology, including reef and shore-line geomorphology, and one on the land flora. The papers vary in comprehensiveness and quality, but show vast diligence and great erudition. Their scope certainly indicates that the statement by Corner in the summary (p. 621): "We gathered so much information that, when it is published, the Solomons will become one of the better known groups of Pacific Islands" is clearly no exaggeration.

It is impossible, in any reasonable space, to critically review such a book. It seems best to say that, except for those concerned only with land vertebrates, anyone interested in island biology will find many papers that will amply reward his attention. To read carefully and digest the whole volume would take even a rapid reader a substantial amount of time.

It is regrettable that the Royal Society conservatively adheres to an outmoded format of a single colum 6 1/4 inches wide. In addition to being very uneconomical, it is distressingly fatiguing to the reader and greatly shortens his attention span.

<u>Barkley, R. A., Oceanographic Atlas of the Pacific Ocean, Honolulu, University of Hawaii Press, 1-20, 156 Figs., 1969, $30.00</u>. This important and attractive new Pacific atlas is concerned with physical properties of the waters between 10 m and approximately 2,000 m. Density, dissolved oxygen, salinity and temperature are plotted in fresh detail on trimonthly charts and on latitudinal and longitudinal sections.

The atlas incorporates some three million individual observations accumulated over half a century, processed and edited for the purpose. The author uses a distinctive notation, by plotting his variables on density surfaces (in sigma-t notation), and not on the isobathic ones most commonly encountered in marine atlases. Density also appears as the ordinate in 34 ocean sections. In a useful introduction, Barkley points to the distinct advantages of water density as the independent variable in charts and sections, including the depiction in clear detail of very steep gradients near the ocean surface despite the very small scale of whole ocean charts and sections. A trimonthly series of charts for the 10 m isobath is an exception to the use of density surface charts. Its inclusion permits direct comparisons with more conventional charts. Considerable pains have been taken

to illustrate with ten sample charts, the densities of observations behind the mean values plotted. At a glance data may be judged adequate off the coasts of Japan and California, to practically nonexistent in parts of the southern ocean. The critical user of this atlas may assure himself further of the quality of data in a sampling for each chart of fourteen ten-degree Marsden squares, scattered about the ocean and representing diverse geographical situations. Where data exist histograms have been included and arranged for convenient comparison, to show 1) density of observations in the square, and 2) distribution of observed values according to frequency classes.

All charts and histograms are reproduced in black and white; the sections in three colors, black, red, and shades of blue. Attractiveness and legibility are enhanced by the use of lines of balanced and contrasting boldness and by clear reproduction.

Barkley's atlas would find a useful place in the personal libraries of a good many readers of the ARB were its price at least a third lower. No research library concerned with marine subjects should be without it.

Bryce G. Decker

Maxwell, W. G. H., Atlas of the Great Barrier Reef. 1-258, Elsevier Pub. Co., Amsterdam, London, N. Y. 1968. $32.50. The Great Barrier Reef, lining much of the Queensland coast, is the most extensive, massive, and impressive organic reef feature on earth, at least in present times. It has been studied intensively by geologists and biologists for at least 80 years and more superficially much longer. Although it is not difficult to write an over-all treatise on such a phenomenon before much work has been done on it, it becomes nearly impossible after such an enormous amount of data has accumulated as is now available for the Great Barrier Reef. That one man had the courage to try it is remarkable and enormously to his credit. That he succeeded even reasonably well is even more so. Although the author is a geologist, this work is physical geography in the best and most professional sense.

After an introduction which rather inadequately summarizes the nature of reefs and environmental conditions favorable to their development, a regional geological picture is drawn that admirably sets the stage for geographic understanding of the occurrence of such a major earth feature. The nature and behavior of the water masses, and their relations to bottom topography follow, amply illuminated by charts and diagrams. The intensely interesting geomorphology of the area is well portrayed, and a lucid section on tides and their effects is provided. To complete the regional geography (physical) a chapter on the climate is included, but with little attempt to relate it to coral reef phenomena.

In chapter 6 we come to the real meat of the book. After a critical essay on reef classification and the establishment of a nomenclature suitable for discussion of the details of the Great Barrier Reef, the author describes and illustrates the morphology of the principal features of the Reef with great effectiveness, but without so much detail that would smother the reader. Maps and photos are provided in profusion and are well chosen and reasonably well reproduced. The atlas format chosen for the book is ideal for presenting this kind of information.

Considering that the coral reef is essentially a biological phenomenon, even though it produces geologic and geographic results, the chapter on Biological Observations is a disappointment. The overwhelming diversity of organisms clearly daunted the author when it came to attempting an interpretation of the synecology of the reef. He merely lists and illustrates the gamut of forms, with causal observations on the roles of some of them. This chapter will be useful in enabling the physical scientists using the book to roughly place the organisms he sees on the reef, but will be of relatively little help to the ecological biologist.

The chapter on Sediments is very thorough, with analyses and distribution maps showing an extremely complex series of facies patterns, undoubtedly reflecting the complex nature of the reef structure and its relation to the non-reef land-mass adjacent. The intricacy of the maps suggests thorough and detailed sampling, but no information is given on the sampling procedures used. Hence it is impossible to know just how much of the detail to ascribe to the data and how much to extrapolation. The analyses bring out very well the contribution of the different classes of carbonate-secreting organisms, both animals and plants. A textural analysis, illustrated by histograms and accompanying photos, is also very instructive. This chapter ends with a very brief consideration of sedimentation processes, based on the data presented.

It is indeed remarkable that the vast amount of information presented could lead only to less than 1 1/2 pages of Conclusions. This is perhaps the most severe criticism that can be leveled at the book--that the author seems much more able at analysis than at synthesis, and that the truly magnificent body of data amassed merit a better attempt at integration. One can also say that, although the reef is a feature of biological origin, biological processes are not much emphasized in the discussion.

The bibliography is meager, indeed, considering what has been published on the Great Barrier Reef. Presumably this indicates that by far the greater part of the data included in the Atlas are products of the author's own investigations.

Regardless of the above criticisms, this is a magnificent piece of work and an absolute necessity for anyone who proposes to do any serious work on the Great Barrier Reef, as well as of great interest and value for those concerned with coral reefs and islands generally. Any geographical library would be seriously deficient without a copy.

F. R. Fosberg

Kohn, A. J. and Robertson, R., The Conidae (Gastropoda) of the Maldive and Chagos Archipelagoes. Jour. Marine Biol. Assoc. India 8: 273-277, 1966. This is a report on collections made by the authors and a zoogeographic summary of the family for the area. 64 species are reported, all but one of them, Conus barthelemyi, widespread.

Kohn, A. J., Microhabitats, abundance and food of Conus on atoll reefs in the Maldive and Chagos Islands. Ecology 49: 1046-1062, 1968. Ecological study of the species listed in the above paper. Theoretical aspects, as well as empirical observations, are emphasized.

Kohn, A. J., Type specimens and identity of the described species of Conus. IV. The species described by Hwass, Bruguière and Olivi in 1792. Jour. Linn. Soc. (Zool.) 47: 431-503, 1968. A detailed study of the 125 names of Conus published in the Encyclopédie Méthodique in 1792. The study was based on descriptions, figures, specimens, and cited references. Most important, however, is the fact that this material was considered in light of a profound knowledge of the genus. The status of a great many names seems to be definitely settled. Conchologists and malacologists, as well as marine ecologists should be most grateful. This is an unglamorous but highly essential kind of work that makes possible sound zoölogical nomenclature.

Storr, J. F., Ecology and oceanography of the coral-reef tract, Abaco Island, Bahamas. G.S.A. Spec. Pap. 79: 1-98, 1964. A comprehensive and beautifully illustrated ecological description of a reef-tract in one of the coral reef groups closest to the U. S. It will inevitably serve as a text-book and a guide-book for American marine ecology students when their professors awaken to the fact that they have a remarkable demonstration area for field work almost in their front door-yard. Habitat factors and topography are described in detail, faunistically characterized zones defined, the distribution of plants and animals elucidated, and brief conclusions drawn as to the relationships of these phenomena.

Bakus, G. J., Energetics and feeding in shallow marine waters. Int. Res. Gen. Exper. Zool. 4: 275-369, 1969. This essay attempts to understand the ecological processes surrounding the production and consumption of organic matter on marine shores, and to compare this complex of processes and behavior in tropical and temperate waters. Coral reefs

characterize many tropical shores and are given much attention. The paper will unquestionably be the basis on which future research in this field will be built, and as such it amply merits the attention of marine ecologists planning to work on coral reefs.

Roads, C. H., Ormond, R.F.G., Campbell, A. C., and Polunin, N.V.C. Report on the 1969 Red Sea Expedition of the Cambridge Coral Starfish Research Group into the starfish Acanthaster planci. 1-11 + 24 pp., 1970. The above outsize title leaves little to be said about this interesting document, except that the authors did find and study apparently normal populations of the crown-of-thorns starfish. The report, though extremely preliminary, is interesting enough that anyone seriously concerned with the ecology of this destructive animal can scarcely afford not to read it. The expedition will be continued on an augmented scale in 1970. The Sudan coast of the Red Sea, including Wingate and Towarit barrier reef islands, is the area studied.

Robertson, W.B., Jr., Transatlantic migration of juvenile sooty terns. Nature 223: 632-634, 1969. A further installment of the results of Bill Robertson's continuing work on the sooty terns of Bush Key, Dry Tortugas, reports the results of an enormous banding effort. The amazing thing to come out of this is conclusive evidence that the juvenile terns from the Dry Tortugas colony migrate to the Gulf of Guinea, West Africa, returning sometimes during their first six years. The paper is fascinating. In the same context, the Smithsonian Institution's Center for Short-Lived Phenomena, on July 11, 1969, published a report by Bill Robertson of a massive failure of the 1969 sooty tern egg hatch on Bush Key. The cause is not evident.

Guilcher, A., L'Océanie. 1-295, Presses Universitaires de France, Paris, 1969. A general geography of the Pacific of which about one-third is devoted to Australia and New Zealand, so that the many archipelagoes of small islands are discussed in only two to a few pages each. The text is up-to-date and makes useful and informative reading. Illustrations include diagrams, maps, and photos. This small volume will be a good introduction to the Pacific for the general reader as well as a valuable reference for the specialist in need of checking some of his facts and figures.

Guilcher, A., et al., Les récifs et lagons coralliens de Mopelia et de Bora-Bora (îles de la Société). Mémoire ORSTOM 38: 1-103, 1969. Preceded only by a few preliminary papers, here are at last the main results of the 1963 Expedition (cf. ARB 100:1, 1963) led by Professor Guilcher, and sponsored by the Foundation Singer-Polignac and Centre National de la Recherche Scientifique. The report compares a small atoll and the barrier-reef of a high island in their morphology, sedimentology and water circulation. Further comparisons are made with other atolls and reefs. The memoir is generously illustrated with maps, graphs and air-photos. Results of the botanical studies are not included, and will be published separately. There is an English summary.

Société des Océanistes: The Journal for Dec. 1969, received a few months later, is devoted to the Missions in the Pacific and includes also the usual notes, reviews, and the latest installment (for 1968) of the Bibliographie de l'Océanie. This is vol. XXV, no. 25. Almost by the same mail no. 26 arrived, which is the first issue of a new series: the Journal will be quarterly from 1970 on, with nos. 26-29 to form vol. XXVI. This number has 92 pages as against 458 for no. 25, fonts and design (except for a new cover) remain the same. An index for 1960-69 will be included in vol. XXVI. We trust that the coverage will continue as in the first series so that in addition to the sciences related to Man in the Pacific, some attention will remain focused on his environment. The varied, eclectic and yet harmonious choice of topics in the Journal has always been one of its great assets. We wish it all possible success in its new format.

Cahiers du Pacifique: Two issues were received recently: No. 12, dated Dec. 1968 and 13, May 1969. Both include papers on French research on Mururoa and other Tuamotu atolls affected by the nuclear experiments of 1966-68. The field work started in 1964 (borings) and continued at least into 1967 and constitutes apparently a "before" phase of study of the atolls. Whether any "after" surveys have been made and the publication of their results planned is left unsaid. All these papers are also collected in one volume, "Mururoa," issued by the Direction des Centres d'Expérimentations Nucléaires, Service Mixte de Contrôle biologique, 1-333, 1969. Both Cahiers du Pacifique include the usual section of Nouvelles du Pacifique; no. 13 has also a number of articles on Pacific crustacea and fungi. As always, the Cahiers are lavishly illustrated, with line drawings, maps and plates including 4 in color.

Reefs of New Caledonia: The results of the 1960-63 Expedition to New Caledonia, sponsored by the Fondation Singer-Polignac, are being published as a series of Memoirs by the Fondation (ARB 112: 10, 1965; 117:4, 1966). Vol. 1, 1965, includes an account of the Expedition by B. Taine and a geomorphological description of the southern reef of the island by A. Guilcher (with English abstract). Vol. 3, 1968, by J. P. Chevalier, includes 3 papers on the geomorphology, modern reefs and fossil madreporaria of Maré I. in the Loyalty group, a raised atoll with two small basaltic islets in the lagoon. Vols. 2, 1964 and 4 (in press) include papers by various authors on the zoological collections and other observations of the Expedition. The first preliminary volume on Polynesian decapods has been followed by a second, by D. Guinot (1967), on Indo-Pacific edible crabs (not seen). All the volumes seen are very handsomely designed and illustrated.

Clipperton Island: Quite a number of mimeographed reports on the French observations made on Clipperton (see ARB 126: 4, 1969) have been received. One of the most recent, BIO-ECO No. 61, Jan. 1970, by P. Niaussat et al., concerns the microbiology of the Clipperton lagoon. Other subjects of research have been the biology of land crabs, birds, molluscs, and fish poisoning. Some of these valuable reports are mentioned, with annotations, in the recent Cahiers du Pacifique.

Les oubliés de Clipperton, by Claude Labarraque-Reyssac (1-249 +2, André Bonne, Paris, 1970) is a historical novel based on the ordeal of the Mexican garrison abandoned on Clipperton Island in 1914 after a change in government, and rescued only in 1917 when reduced to a dozen women and children. The author, French novelist and playwright, has made every effort to provide an authentic background to her story and the book includes a map, a photo and a short bibliography of the island.

Bermuda: Bermuda Biological Station for Research, St. George's West, Bermuda, asks us to mention the availability of a revised edition of H. B. Moore's Ecological Guide to Bermuda Inshore Water, B.B.S.R. Special Pub. 5, 1969, at $2.00 per copy. Sets of their Contributions, 7 volumes, 1903-1942, are still available at $100.00 per set. They have also just published their Special Publication 1, Distribution of Marine Algae about Bermuda, by Wm. Randolph Taylor and Albert J. Bernatowicz, 42 pp., 1969, $1.75. It lists the common shallow water species, with detailed localities, seasonal development and fruiting periods.

The Great Barrier Reef: W. J. Dakin's "The Great Barrier Reef, and some mention of other Australian coral reefs", first published in 1950, has been re-issued as a paperback in the series Walkabout Pocketbooks by Ure Smith Pty Ltd in Sydney and by Horwitz Group Books in London. The re-issue is of the second edition (1963), revised by Dr. Isobel Bennett of the University of Sydney. The paperback version is lavishly illustrated in both color and black & white, and sells for $ Aust. 1.50, about US $ 2.00.

Indian Ocean Bibliographies: The Central Marine Fisheries Research Institute, Mandapam Camp, India, has recently issued a "Bibliography of marine fisheries and oceanography of the Indian Ocean 1962-1967" as the first in a new series of Bulletins, 208 pp., 1968. The bibliography contains some three thousand citations, and is designed to bring up to date the "Partial Bibliography of the Indian Ocean", compiled by A. E. Yentsch and issued by the Woods Hole Oceanographic Institution in 1962 as part of the U. S. Program in Biology of the International Indian Ocean Expedition. The Indian bibliography follows the same arrangement as the earlier work, though unfortunately the section on Coral Reefs (Geology and Biology) has been omitted. Both bibliographies have an author index but no regional index. The Central Marine Fisheries Research Institute has also issued "An annotated bibliography on the breeding habits and development of fishes of the Indian region" as Bulletin 3: 154 pp., 1968.

Woodward, R. L., Jr., Robinson Crusoe's Islands: A history of the Juan Fernandez Islands. 1-272, 1969. We have not seen this book and do not even have a complete reference to it.

Domm, S. and A., A visitor's guide to Heron Island and the Capricorn Group, Great Barrier Reef, Australia. 1-48, [Sydney, 1969?], published and distributed by the authors. This is a simply written and very well illustrated guide to the geography and natural history of these islands at the southern end of the Great Barrier Reef. It should be in the hands of every visitor.

Amos, W. H., Limnology, an introduction to the fresh water environment. 1-40, Chestertown, Md., 1969. Describes fresh-water bodies and suggests research activities and methods. Well illustrated with diagrams and photos. Some of the types of investigation mentioned should be undertaken on the occasional fresh-water pools, swamps, marshes, and bogs on atolls, which have been little studied. We know even of a few fresh or almost fresh-water lagoons, as on Swain's, Washington, and Clipperton atolls.

Briefly noted items: By the time this issue appears, the Supplement to our Island Bibliographies will be closed to further additions and at least on the way to being printed. We have no intention to carry this enterprise farther, as it has consumed an inordinate amount of time and energy. We will, however, in each Island News and Comment number of ARB, list published items that come to our attention, and that we feel might be useful or interesting to ARB readers. We will not attempt to organize them, except alphabetically, nor to offer complete coverage, nor even pretend that we have seen and read all items.

Faure, H. and Roubet, C. Découverte d'un biface acheuléen dans les calcaires marins du golfe pléistocène de l'Afar (Mer Rouge, Ethiopie). C. R. Acad. Sci. Paris, 267 (D): 18-21, 1968.
Acheulian implement in place in reef elevated to 90 m, Danakil depression. DRS.

Franzisket, L. The atrophy of hermatypic reef corals maintained in darkness and their subsequent regeneration in light. Int. Revue Ges. Hydrobiol. 55: 1-12, 1970.

High, L. R., Jr. Storms and sedimentary processes along the northern British Honduras coast. Jour. Sed. Petrol. 39: 235-245, 1969.
Mainland coast.

Jeffrey, C. Coco-de-mer. New Scientist, no. 372: 34-37, 2 January 1964.

Kendall, C. G. St. C. and Skipworth, P. A. d'E. Geomorphology of a recent shallow-water carbonate province: Khor Al Bazam, Trucial Coast, Southwest Persian Gulf. G. S. A. Bull. 80: 865-892, 1969.
Describes coral reefs and mangrove swamps; photos. FRF.

Montaggioni, L. Répartition et zonation géomorphologique des structures récifales de l'Ile Réunion (Océan Indien). C. R. Acad. Sc. Paris 270: 663-665, 1970.

An important, though brief description of the Réunion reefs, relating their characteristics to physical environmental factors. FRF.

Moore, J. G. and Fiske, R. S. Volcanic substructure inferred from dredge samples and ocean-bottom photographs, Hawaii. G. S. A. Bull. 80: 1191-1202, 1969.

May have some bearing on subsidence of islands. FRF.

Neumann, A. C., Gebelien, C. D. and Scoffin, T. P. The composition, structure and erodability of subtidal mats, Abaco, Bahamas. Jour. Sed. Petrol. 40: 274-297, 1970.

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Robertson, R. Review of the predators and parasites of stony corals, with special reference to symbiotic prosobranch gastropods. Pac. Sci. 24: 43-54, 1970.

Scoffin, T. P. The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. Jour. Sed. Petrol. 40: 249-273, 1970.

Shier, D. E. Vermetid reefs and coastal development in the Ten Thousand Islands, Southwest Florida. G. S. A. Bull. 80: 485-508, 1969.

Intertidal masses of Vermetus shells forming a reef rock. Geological study. FRF.

Seuss, Erwin. Calcium carbonate interaction with organic compounds. 1-153, PhD. Thesis, Lehigh Univ., 1968 (ONR Geophysics Br. N-onr-610 (07), report and contract No.).

Beachrock cementation?

Swinchatt, J. P. Algal boring: a possible depth indicator in carbonate rocks and sediments. G. S. A. Bull. 80: 1391-1396, 1969.

Interesting, but no evidence that author has any idea what algae are doing the boring. Does think boring takes place subtidally; no mention of terrestrial boring algae. FRF.

Taylor, J. D. and Lewis, M. S. The flora, fauna and sediments of the marine grass beds of Mahé, Seychelles. Jour. Nat. Hist. 4: 199-220, 1970.

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Weydert, P. Les variations récentes du niveau marin et leurs influences sur la morphologie récifale dans la Baie de Tuléar (Sud-Ouest de Madagascar). C. R. Acad. Sc. Paris 268 (D): 482-484, 1969.
Ascribes reef morphology to recent eustatic shifts in sea level. Interesting. FRF.

Aldabra Bibliography Supplement: Since the publication of the "Bibliography of Aldabra" (Atoll Research Bulletin, 118: 127-141, 1967) many additional items have been traced. Some of these were omitted in error from the Bibliography literature search and have since been noted; more have been brought to my attention by correspondents (notably Mr J. F. G. Lionnet of Mahé, Seychelles); and finally, a number of items have been published since the Bibliography went to press.

I am sure that the Bibliography, even with these additions, is very incomplete. Hence I am circulating a Supplement so that members can check their own records and identify additional items not yet entered. I would be very glad if you could send them to me, so that they can be incorporated in a final version.

The criteria for inclusion of items remain rather loosely defined. In some cases descriptions of new taxa from Aldabra are included, in others not. Species lists are generally included, even when only a single record for Aldabra is contained in them. Much of the recent (1967-) literature is clearly ephemeral, but I have included it in the Supplement except in the case of such items as unsigned editorials and newspaper articles. In some cases I have been unable to check items in the Supplement and some of the citations are incomplete: I would be glad to have any corrections or changes to these.

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